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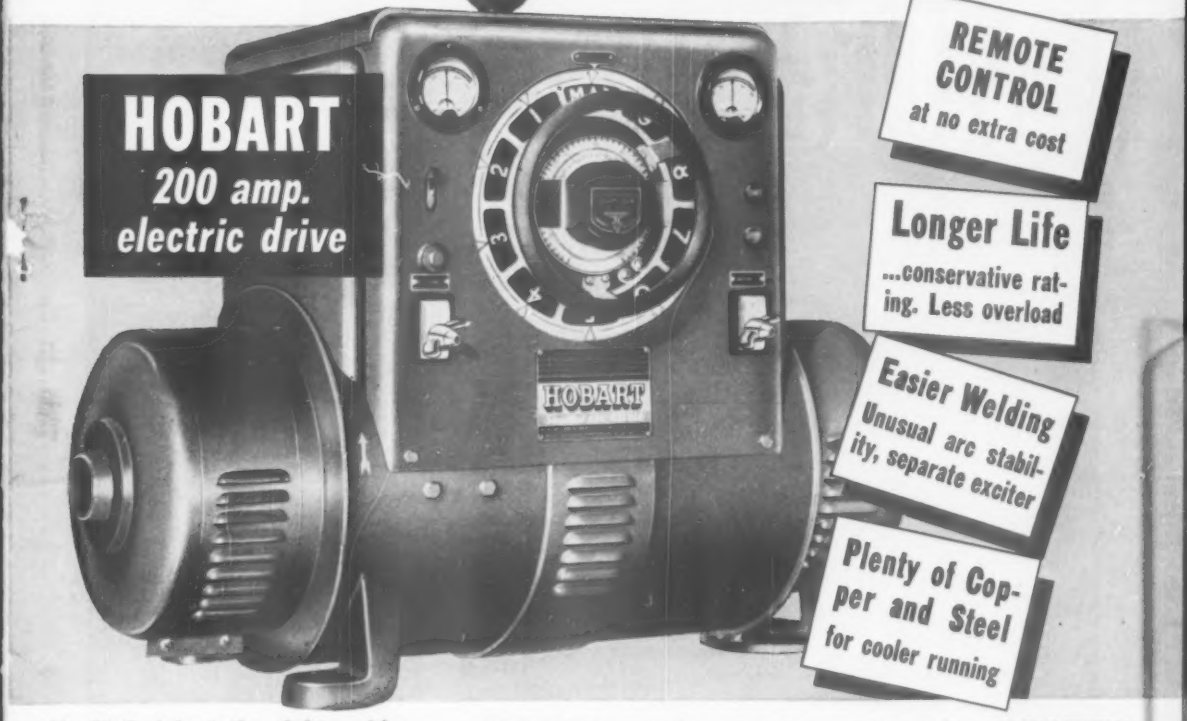

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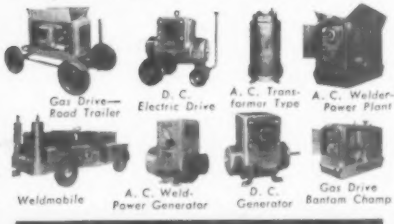

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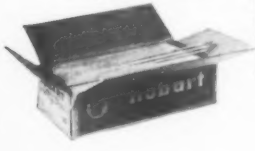

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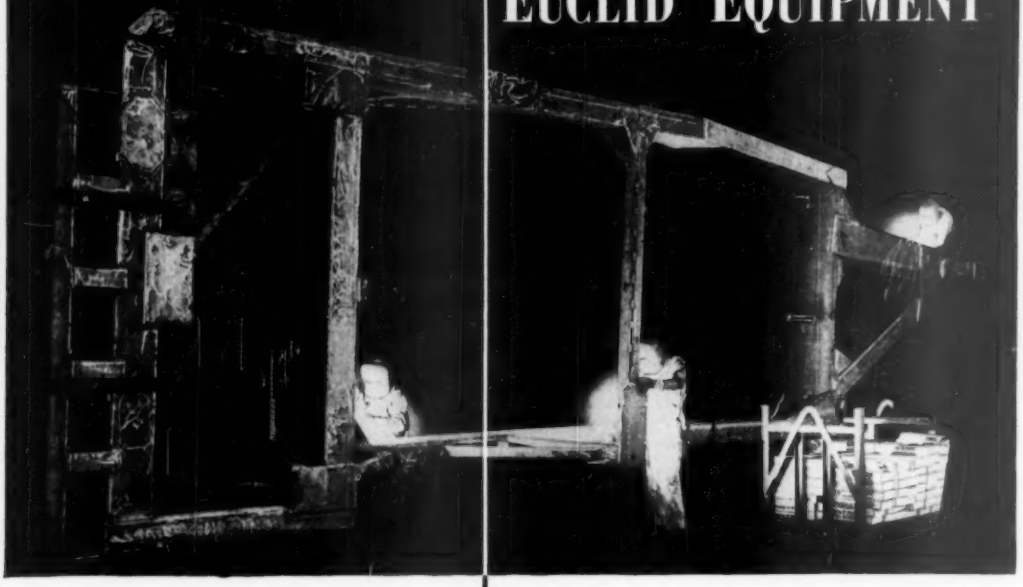

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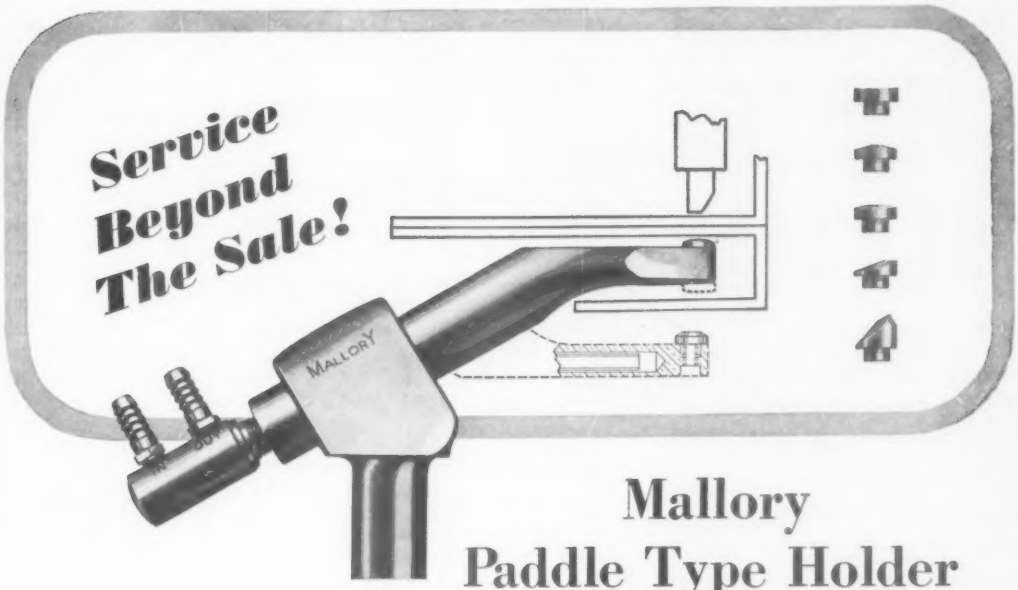

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cover: Two men with gun welders are shown welding the component parts into a strong, shock-resisting body. *Courtesy Fisher Body Division, Detroit, Michigan.*

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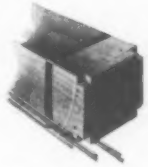

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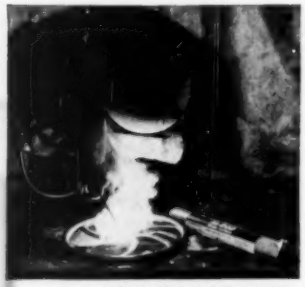

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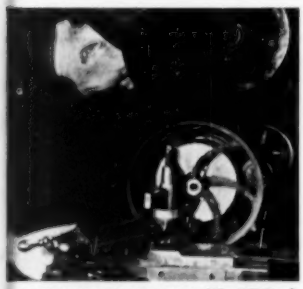

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The WELDING JOURNAL

volume 29 April 1950 number 4

Progress in Rail Pressure Welding

Historical review and modern practices in pressure welding rail and résumé of actual experience with this type of joint

by Lem Adams

NEARLY a decade ago, the oxyacetylene pressure welding process for welding standard 39-ft. rail into long lengths of continuous rail was described at an AMERICAN WELDING SOCIETY meeting. At that time the process was just being introduced to the railroads. As the process has been given such wide acclaim by the railroads since its introduction, it would be of considerable interest to the AMERICAN WELDING SOCIETY to have some information on the present-day state of the art.

At the previous meeting of the AMERICAN WELDING SOCIETY, reference was made to an 1874 copy of *Trautwine*, a standard reference on track engineering, to illustrate the point that continuous rail is not a 20th Century idea. Further research has turned up some far earlier history on the idea of continuous rail. For instance, in Fig. 1 you see details of the English Barlow rail that was riveted together into 3-mile lengths in 1855. Under this 15,000-ft.-long continuous rail, crushed material was used for support, the rails being held together by tie bars spaced every 10-ft. It is said that no expansion difficulties developed.

Although it was surprising to find this 1855 use of riveted continuous rail, you can imagine our amazement to come across an 1821 patent filed by the English engineer, John Birkenshaw, that referred to this subject. In Birkenshaw's patent application for rolled T-shaped wrought iron rail, he said, "In order to remedy the evil arising from the Rails being imperfectly joined, the plan of welding the ends of Rails together has been adopted; by this means, making one continued rail the whole length of the road without any joint whatever." This part of the patent was never carried out because there was then no practical welding method.

Birkenshaw's dissatisfaction with the joints in rail marked the beginning of much unhappiness on the part of railroad engineers and others about this weakness. The century was notable for the developments of better mechanically fastened joints, for the introduction of steel rails and for the production of longer rail lengths. The comparative chart, Fig. 2, shows the constant growth of rail lengths from 1672 to 1925. In the latter year the 39-ft. rail length was made standard on American railroads and is still today's standard.

For the first couple of years of

Lem Adams is Vice-President, The Oxweld Railroad Service Co., Chicago, Ill.

Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

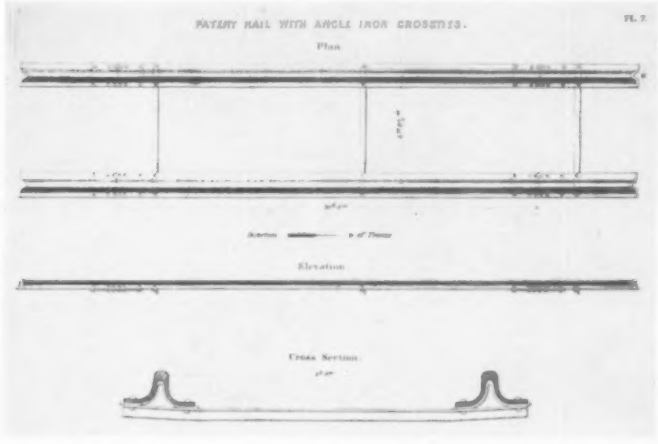


Fig. 1 Rail of this pattern was riveted into solid three-mile lengths in 1855

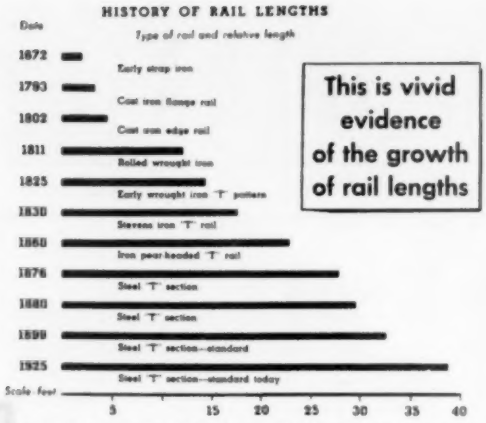


Fig. 2 Diagram to show the constant progress in increasing rail lengths

continuous rail production by oxyacetylene pressure welding, the work was performed on cars. The welding machine was in a box car or on a flat car and the other stations for finishing the welded rail were mounted on the floor of a string of flat cars. This physical setup had its advantages but had to be abandoned during the late world war because of the demand for railroad cars, and it was found more feasible to operate the equipment on the ground. This, of course, required some additional time for getting the outfit set up on a production line. However, it is now common practice to unload the equipment and get the job in full swing within two or three days.

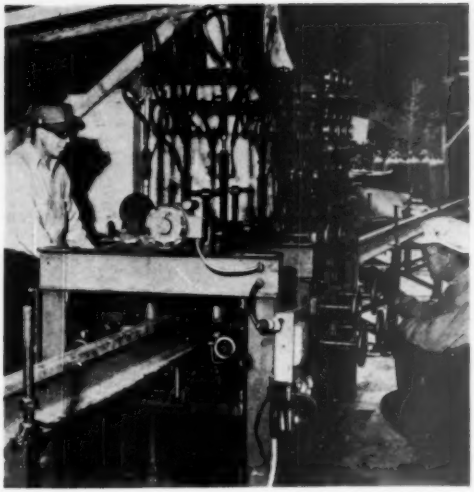


Fig. 4 Present model of rail pressure-welding machine, one-half the weight of machine made in 1937

Figure 3 shows a typical setup at which over 5000 welds were made. You can see the rail stockpile, the welding machine, the trimming station, the normalizing machine and the grinding stations. Note that the operators are fairly well sheltered from inclement weather. This makes for comfort and hence better production. From a weld quality standpoint it is especially valuable to have the welding machine in good shelter as wind currents make it difficult to produce an even heat in the weld area.

While on the subject of the welding machine, some of the improvements made in the past few years are note-

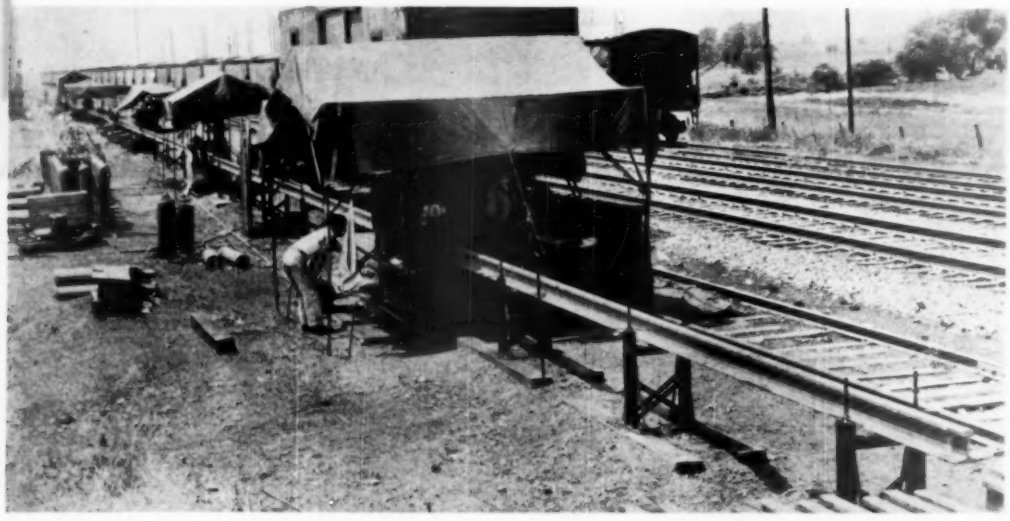


Fig. 3 Recent typical oxyacetylene rail welding setup with welding station in foreground

Fig. 5 The blade in this saw is used to prepare rail ends for welding

worthy. In the first welding machines made, two hydraulic clamps were used to grip the rail and two others exerted the end-to-end pressure needed for this process. This arrangement required that clamps be provided to fit each individual rail size. However, a simpler clamp that will grip any standard rail regardless of size is now used. It still depends upon friction as the holding agent. Welding machines now being built have the new clamp installed and the older machines are being re-vamped by the addition of this more efficient device. The new clamp requires fewer adjustments by the welding operator, it retracts more easily at the completion of each weld and there are fewer parts to maintain. The type welding machine that is now being produced to keep up with the demand for welded rail is shown in Fig. 4.

Figures 5 to 13 show the step-by-step operations in pressure-welding rail. Before welding, the rail ends must be square, and free of rust, dirt or other impurities. As shown in Fig. 5, the ends of two rails are butted together and clamped under the blade of a power saw. The blade, $^1/_{10}$ in. thick, saws through the abutting surfaces, squaring them, and providing clean

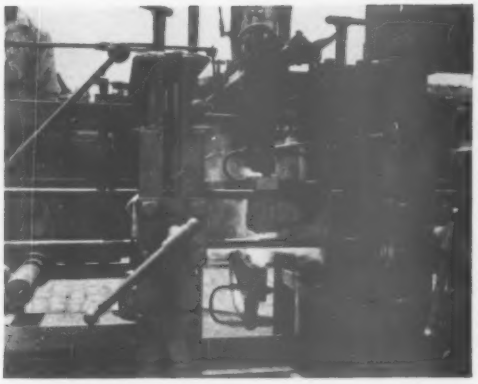


Fig. 6 Close-up at side of welding machine shows heating heads and rail

metal for welding. If there is much time between sawing and welding, a thin coat of grease is applied to the freshly sawed rail ends to prevent oxidation.

Not all railroads use the saw method to prepare rail ends for welding. Instead, the rails are delivered mill-end finished and at the welding site the rail ends are cleaned by light grinding before they are placed in the welding machine.

The welding performed in this machine, Fig. 6, is essentially a simple operation. At the completion of a weld in a long string, a power winch pulls the long string ahead for a rail length and at the same time another rail is pushed on rollers into the machine. Inside the machine the ends are left a few inches apart so that the operator can clean off the ends to be welded with ethylene dichloride or some other suitable agent. Following the cleaning, the ends are shoved to an abutting position and the power is turned on to tighten the clamps. As the clamps tighten, the hydraulic rams shove the rails together with a pressure of approximately 2700 psi.

By turning quick-acting shut-off valves, the flames from the four heating heads are turned on. The oscillating mechanism moves the flames slowly back and

Fig. 7 Flame cutting the upset metal on the top and sides of ball

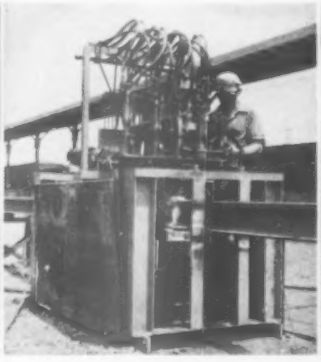


Fig. 8 Normalizing machine to reheat the weld area

Fig. 9 Grinding the running surface of the rail with a power grinder

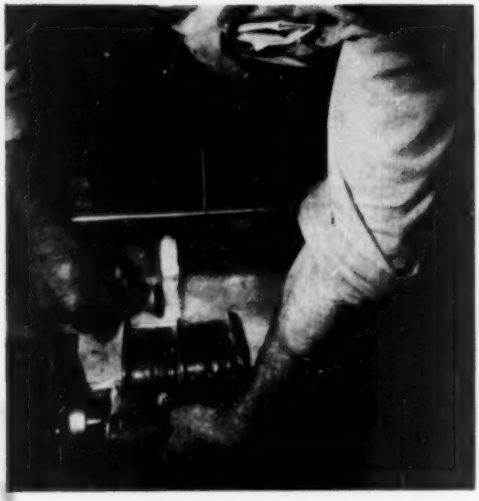


Fig. 10 Testing the weld area for defects with iron powder and magnet

forth through a 2-in. cycle. As the heated area approaches 2200° F., the ram pressure forces the rails together. In 132-lb. rail the welding time is from 5 to 6 min. There is a very short cooling period while the clamps are loosened and retracted Then the winch is signaled to pull the rail from the welding machine.

Figure 7 shows the upset metal being trimmed from the rail with a hand-cutting blowpipe. The simple guide for the blowpipe permits quick, accurate removal of the upset from the top and sides of the ball and from the sides of the base. On most welding jobs this hand-trimming is done by the operator of the normalizing machine.

By the time the weld reaches the normalizing machine, which is located another welding station away, the temperature has dropped below the critical. The normalizing machine (see Fig. 8) is much like the welding machine in appearance; that is, the welding heads

Fig. 1 Moving continuous rail which is slung under push cars

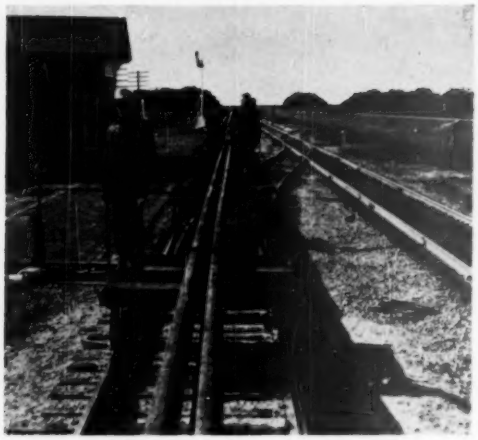


Fig. 12 Long rail strings being moved on push cars

are quite similar. However, in order to include all of the previously heated area, the flame travel is here extended to approximately 6 in.

A normalizing temperature of approximately 1500° F. is used, and is constantly checked by the use of temperature-indicating crayon. This check is made several times a day in order to make allowances for atmospheric conditions. It requires an average of

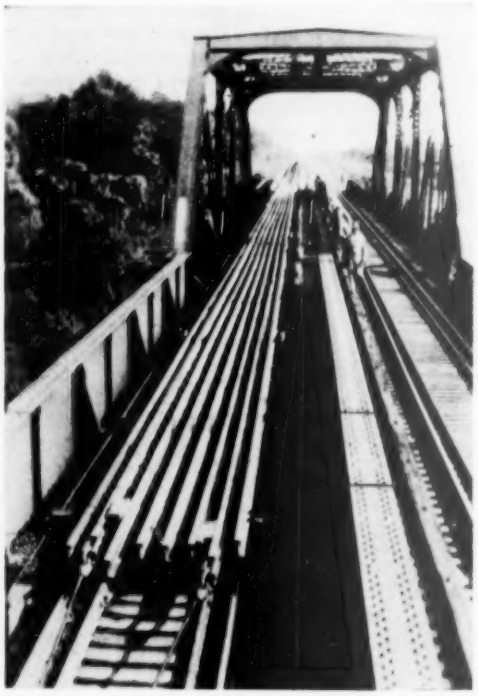


Fig. 13 Group of continuous rails being skidded on ties that are fitted with skid plates

Fig. 14 The E. J. & E. Railroad uses 43 flat cars to move continuous rail to site of laying

Fig. 15 Continuous rail is fed from the welding line onto the rollers on the flat cars

Fig. 16 Flat cars filled with continuous rail easily negotiate curves and switches

about 5 min. to normalize the weld properly. Note that the top heating head is set at an angle across the rail in order that the wheel tread will strike the heated area on an angle. This is done because in the initial stage the weld area is somewhat harder than the adjacent rail surface. The adjacent surface is in the decarburized state, whereas, in the welded area the decarburized surface has been removed. Further, there is a slight reduction in hardness in a very narrow band at the end of the flame travel.

Grinding the running surface and sides of the rail are not unusual in any respect. Figure 9 shows a motor-driven grinder being used to smooth the running surface.

Since the Oxweld Pressure Welding Process is not entirely automatic, there can, of course, be man failures. Therefore, some few years ago a magnetic particle tester was introduced to test welds for surface separation. This method of testing keeps the operators on their toes, so that they produce sound welds. In this connection it might be of interest to note that out of approximately 100,000 welds which have been produced by this process to date, only 27 failures from all causes were experienced. A considerable percentage of this small number was due to experimentation in the field.

Figure 10 shows the simple testing mechanism in use. The entire weld area is explored on every weld that is made. Experience shows that if no surface checks are indicated, then a perfect weld has been made, as it is apparently impossible to have any inner defect without it being carried to the rail surface.

On large welding programs, it is common practice for the welding crew to get an output of 40 to 50 welds in an 8-hr. working day since it is a simple matter to produce 6 welds per hour. Obviously, with small jobs and an inexperienced crew, the average production will be very much lower because it requires some time to get a working line into production. Each man has to learn to perform his duties and to get them coordinated with the welding operator, the key man on the line.

During the past ten years it was natural that many methods of transporting long rail from welding site to site of placement in track should develop. Figure 11 shows a method in which U-shaped hangers were used to move a long string out onto a bridge by means of a series of push cars. Figure 12 shows two long strings on push cars, spaced about 40 ft. apart. At the laying site one continuous string was manually pushed off one side of the push cars, the other string off the other side. Figure 13 shows another method. Here eight rail strings are being skidded on the track, pulled by a locomotive. This rail negotiated a curve quite readily. This was a heavy load to skid and it is not considered the best method if too much weight must be moved.

The shortage of cars during and after the war has undoubtedly been a factor in the methods railroads have adopted for moving long rail. This contention is made because shortly after the end of the World War II the use of flat cars to transport welded rail was again undertaken by the railroad that has embarked on the most ambitious rail-welding program undertaken by any United States railroad.

Figure 14 shows a string of 43 flat cars that are coupled up at the end of the welding line on the Elgin, Joliet and Eastern Railroad. This line of cars permits the production of 1560-ft. rail lengths. As the welded strings leave the welding line they are shoved over a series of rollers that are mounted on the cars. These rollers are seen close up in Fig. 15. Note that there are 12 rollers, providing for the same number of welded strings. These flat cars, assigned to move the welded rail, provide space enough for about six day's production of welded rail. On this railroad, the week's production is hauled out on the line of flat cars and distributed to laying sites on Saturday or Sunday, when traffic is not particularly heavy. The string of flat cars loaded with rail in Fig. 16 are being hauled by a Diesel locomotive. Note the curve which is easily traversed by the massed group of welded rail strings.

To remove the continuous rail lengths from the flat cars, a special clamp assembly securely ties the ends of the two rails together. This clamp is shown in Fig. 17. A cable extends from the clamp to the winch

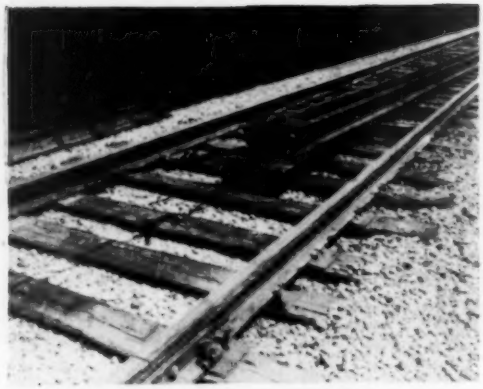


Fig. 17 The clamp holds two rail lengths while a Diesel locomotive pulls the flat cars from under the rails

of a locomotive crane. The crane, with its brakes set and its wheels blocked, acts as a dead-man, holding the two rails immovable as the flat-car train is pulled out from under them. The rails are unloaded in the center of the track, and immediately after each pair is off the cars the locomotive crane, shown in Fig. 18, moves ahead progressively. With successive grabs,

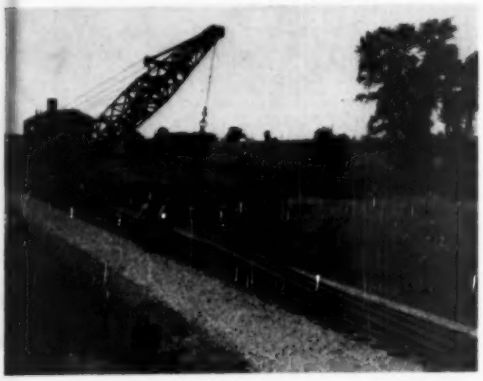


Fig. 18 Work crane setting out continuous rail to shoulder

Fig. 19 Light work crane lifts one rail back to center of track just prior to laying

about 100 ft. apart, the crane sets the rails out on the track shoulder.

The foregoing is the method used by the Elgin, Joliet, and Eastern Railroad for distributing their welded rail. The pictures and description following will show how this railroad lays continuous rail with machinery and a minimum of man power.

In the case of the E. J. & E., rail laying is done when the atmospheric temperature is between 70 and 90° F. The first operation, see Fig. 19, is to set the new long rails back in the center of the track, one at a time, with a rail crane. As this takes place, the old rail is stripped of spikes, anticreepers and joint bars. As Fig. 20 shows, the old rail is barred out to the shoulder and then the usual jobs of removing old tie plates, plugging spike holes, adzing, creosoting and placement of new tie plates are done. In Fig. 21 a gang of six or seven men are barring the new continuous rail over on to the new tie plates. After being placed in position the usual rail-laying steps are taken: that is, gaging, mechanical spiking and application of anticreepers.

The E. J. & E. eliminates every possible bar-fastened joint by making field welds in the long lengths by manual oxyacetylene welding. The two operators shown in Fig. 22 are making a field weld in the 132-lb. rail laid by this railroad. Notice the bolt holes in the rail ends. They are used to apply the regular joint

Fig. 20 Barring out old rail to ditch. New continuous rail can be seen

Fig. 21 Six or eight men bar in the continuous rail so that it rests on new tie plates

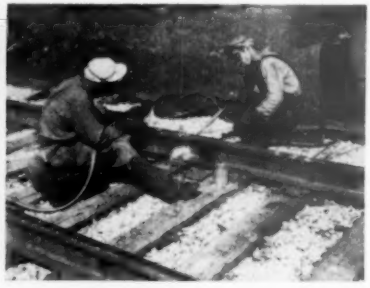


Fig. 22 Making a manual field weld in two 700-ft. lengths of pressure-welded rail

bars as additional reinforcement of the manual field weld. The joint bars have a section of both top and bottom bearing areas removed so that they clear the weld area and thus avoid impingement.

It is worth while to report briefly on the precautions taken by this railroad to prevent expansion and contraction of such long lengths. For the most part, rail anchors are placed on every fourth tie, except near the ends of continuous lengths. In single track territory, the rail is anchored at all ties for a distance equivalent to six 39-ft. rail lengths each way from a joint. In double-track territory, near its ends, each continuous length is anchored at every tie for a distance of four rail lengths in the direction of traffic, and for eight rail lengths against traffic. The longer stretches of rail, in excess of 6000 ft., are also anchored for six to eight rail lengths near the center. It is of interest to report that this railroad has more welded rail than any other United States railroad and that two of their rails are 12,782 ft. long. These are probably the longest railroad rails in the world.

Some of the railroads are now finding it advantageous to double or triple lengthen relayer rails which are to be laid in secondary tracks after having been released from their first position in high-speed main-line track. These rails, of course, have the bolt hold ends cropped, at least on the ends that are to be welded together. This is one method of providing fewer joints to be maintained. In this connection, several railroads have now made it standard practice to weld all of their new rails into double lengths before they are placed in track. This, of course, eliminates half of all the joints in such track.

Welding men are aware of the long conflict between welding and riveting or mechanical fastening. Many difficulties have been encountered by the welding industry in getting the railroads to accept welded boilers. As developers and suppliers of rail butt-welding equipment, it has been our experience that there is considerable resistance to welded continuous rail. There are several reasons for this opposition. One is the ingrained belief of the railroad fraternity—and of the general public as well—that it is impossible to hold long rail so as to prevent, in a practical way, expansion and contraction. The answer to this is that continuous rail *is* being held, practically immovable in every conceivable type of location. A second reason for opposition to continuous welded rail is that its adoption requires original planning and execution.

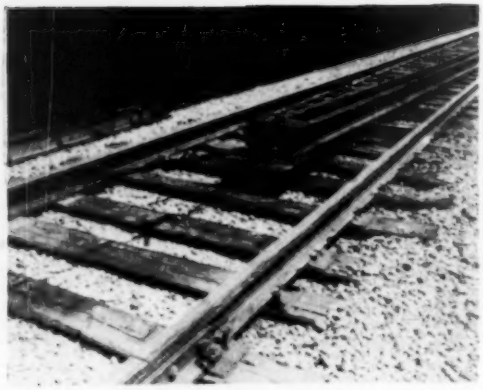
Here is an example of how one small railroad this year faced a continuous rail-welding program with a willingness to adopt original planning and execution. The New Orleans Public Belt Railroad replaced 4½ miles of jointed rail on the Huey Long Bridge. The rail on the bridge was in fair shape except at the joints so the railroad purchased only 400 tons of new rail. Using new rail, they welded a 1200-ft. length of continuous rail, pushed it out on the bridge, removed an equivalent amount of jointed rail and laid the long string. The rail lengths that were removed were brought back to the welding site and cropped on each end to remove batter and bolt holes. These shortened rail lengths were welded into 1200 ft. strings. The welded string was then taken to the bridge to replace more of the jointed rail. This railroad thus ended up with almost four and one-half miles of continuous rail in a very important location. The life of the rail is extended and the harmful vibration of trains crossing conventional joints is practically eliminated.

The third point of opposition to welded rail has been the additional cost of welding. Let us look at this extra cost. Because of higher labor and material costs, a conventional bolted joint installed in track is about twice as much today as compared to ten years ago. Now remember that is just original cost, not maintenance. While installed costs of conventional joints were rising, the welding of continuous rail increased in efficiency to such an extent that the cost of a welded joint has actually declined in the past decade.

Based on production in 1948, one railroad announced that their welded track cost them about $1000 per mile more than conventional. As there were roughly 260 welds per mile of track the extra cost for welding was about $3.80 per joint. Now let us look at the additional $1000 per mile in terms of increased investment. It costs $18,000 per mile to relay track and therefore $1000 additional is less than a 6% increase. Contrast that 6% increase with a decrease in track labor costs of 30% or more which the American Railway Engineering Assn. officially states will result from the use of continuous rail. With respect to track maintenance labor, it is important to know that wage rates have increased 150% in the past decade.

Additional figures on maintenance savings through the use of continuous rail were announced a few months ago. This railroad revealed that their continuous rail resulted in a savings in maintenance costs alone of $390 per mile per year for the life of the rail. That would mean almost $8000 during the life of the rail or eight times the increased cost due to welded construction. This takes no account of longer life for the rail, longer average cross-tie life and decreased wear on motive power and cars.

American railroads which are constantly squeezed between mounting costs and inelastic rate structures cannot afford to overlook any modern method that will help reduce costs. The greatest contribution that the track departments of American railroads could make in reducing costs over the long term would be the adoption of welded continuous rail for the major part of their new rail and relay programs.



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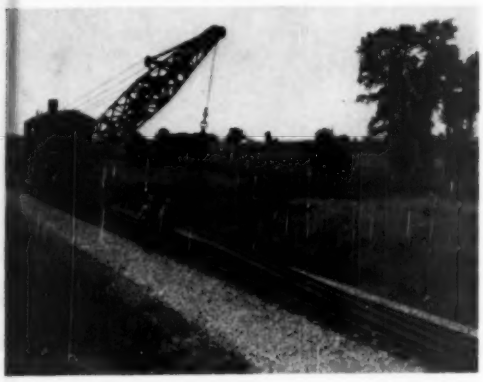

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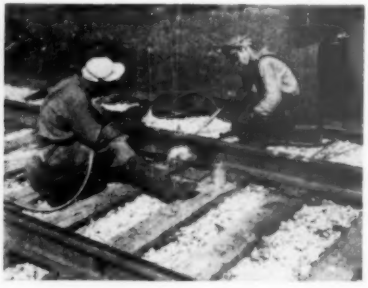

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Stability Tests of Welding Machines

French arc welding specifications are reviewed and the principle of stability tests and methods used and their significance described

by Charles L. Volff

FOREWORD

THE French Arc Welding Specifications Committee, of which the author was Secretary, has issued a tentative specification, described in the following paper, relating to welding apparatus characteristics and how to measure them. They also specify the design of name plates to be fixed on welding apparatus and the minimum information to be given on them.

The suggested tests are as follows:

1. Plotting a curve of voltage against welding current.
2. Temperature tests (this includes the use of a special timer to obtain the functioning at any operating factor, 30, 40, and 60%, the length of each cycle being fixed at 5 min.).
3. Dielectric tests.
4. Stability tests.
5. Efficiency tests.

All these tests are performed according to general rules of electricity, but there is also a new test on stability and the specification describes this test in detail.

STABILITY TESTS

In their previous specification, there was no stability test; requirements being about the same as those of the N.E.M.A.'s. In the paragraph EW4-13 of the N.E.-M.A., under the heading "Stability of Operation," is stated: "The characteristics of the welders shall be such that a trained operator may, under normal conditions, maintain a stable arc and weld satisfactorily at any current value within the specified operating range of the welders."

In the new French specification, after numerous meetings, discussions and experiments, a tentative test has been proposed.

Charles L. Volff is Chief, Electrical and Welding Research, L'Air Liquide Society, Montreal, Canada.

Principle

Two possibilities are offered to the experimenter:

First, by specifying purely electrical tests. Up to the present, for d.-c. current, oscillograms have been used in the two following tests: (*a*) to draw the curve, current vs. time, when the machine is short circuited, and (*b*) to draw the curve, voltage vs. time, when the short circuit is cut out. It is generally assumed, after comparision with actual welders, that certain shapes of curves indicate a better stability than others. A "time recovery" is also specified. For a.-c. current, oscillograms are so difficult to evaluate that they have not been in common use.

Second, to have actual welds made by a good welder, using, under certain conditions, a specified quality of electrodes. Conditions, however, are not always the same, and results from this kind of test are not consistent, for, in addition to the welding apparatus itself, there are other prominent factors likely to affect the results, namely, the welder, the piece to be welded and the electrode. An easily repeated and reliable test of the stability of welding apparatus should eliminate these factors.

To Eliminate Undesirable Factors

It is easy to eliminate the welder factor, by using an automatic arc, but it must be kept in mind that the stability is also controlled by automatic relays and governors, hence it is also necessary to eliminate, if possible, all relays.

To eliminate the piece to be welded, it is advisable to use two similar electrodes, and in order to maintain the same conditions for both, they must be placed horizontally.

The electrode factor is the most important and the most difficult to deal with. To eliminate the quality of the coating, the use of bare wire was suggested, but with bare wires, on a.-c. current, an arc cannot be struck or sustained. Moreover, all metallic electrodes producing drops of liquid metal are functionally unstable, for the process is upset by the drops. The ideal electrodes would be those evolving gas. Finally, it was decided to use two carbon electrodes. Furthermore a

good stability test should include: the striking of an arc, the sustaining of this arc and the lengthening of it, so that the stability of the apparatus may be checked in these different cases.

After many discussions and preliminary tests, the following procedure was adopted.

Stability Test Procedure

Two carbon electrodes of specified quality, 10 mm. diameter, having one end cone shaped with an apex angle of 60°, are prepared. The welding machine (d.-c. and a.-c. generators and transformers) is first adjusted (settled) for a definite welding current, then the welding arc is replaced by the two carbon rods. With their points touching, they are connected to the terminals of the welding apparatus, in place of the electrode and piece to be welded (Fig. 1). When the

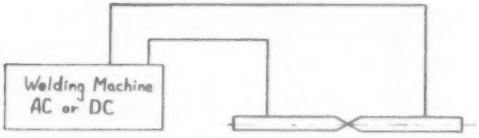

Figure 1

current is switched on, its passage into the two cones meets such a high resistance that the apex carbon is instantly volatilized and an arc is struck. As the experiment proceeds, the carbon continues to volatilize and the arc lengthens. Eventually, the arc cuts off when the stability of the machine is no longer able to sustain it.

To Measure Stability from This Test

The first suggestion is to take oscillograms of voltage vs. time during the test. Unfortunately, as stated previously, it is difficult to evaluate them on a.-c. current.

The second suggestion, a practical one, is to measure the distance between the two carbon rods after the arc has stopped, the current switched off and the carbons no longer hot (disappearance of the red color).

The more stable the apparatus, the greater will be the distance between the carbon rods. However, the distance measured should be the shortest one and not that measured along the rod axis.

On d.-c. current, after a test, the positive electrode is cup shaped, the negative one remaining conical, while on a.-c. current both electrodes are eroded, their ends being plane. The two planes are usually parallel but not vertical, and are often at 45° to the vertical. The explanation of this phenomenon has not yet been determined. Accordingly, the distance to be measured, is the one normal to the planes.

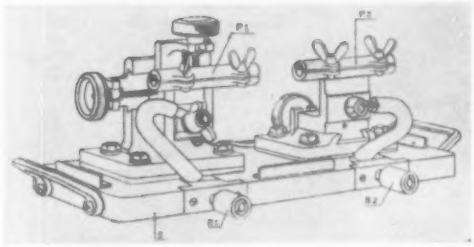

Figure 2

Stability Test Apparatus

A sketch of the apparatus is given in Fig. 2. It is composed of two carbon holders (*P*-1 and *P*-2) placed on a base (*S*) and covered by a cabinet (not shown). On the base are two terminals (*B*-1 and *B*-2). One of the carbon holders (*P*-1) can be displaced vertically and longitudinally; the other (*P*-2) can be moved transversally. This adjustment is necessary so as to have the two apexes exactly touching. In the cabinet is an opening covered with the usual colored glass for arc welding inspection, and also a lamp to indicate when the voltage is on. When the carbons are fixed in their holders with their points opposite each other, the cabinet is replaced on, the terminals connected through a switch to the terminals of the welding apparatus. When ready, the current is switched on and the test proceeds. After the arc is extinguished, the current is switched off, cutting off the light, the cabinet is removed and the distance between the carbons measured, preferably by means of a filler gage.

Test Results

Table 1 gives results obtained with different welding transformers. The setting of the transformer is determined by an actual welding test with an electrode giving an arc voltage of 25 v. (this is standardized arc voltage in France for welding machines), or better, by having a variable resistor, set to have a voltage drop of 25 v., across the terminals.

The distance between carbons is the average of five tests or more in case of discrepancies.

These welding transformers are of the usual self-regulated type and require no resistance or reactance in series. For the constant voltage transformer, the voltage drop was obtained either by a resistance or a reactance.

From the table, it will be noted:

1. The average distance between the carbons increases when the no-load voltage increases.

2. From the figures given for the constant voltage transformer, the average distance between the carbons is greater when there is a reactance instead of a resistance.

These two results agree entirely with the theory of stability and the practice of welding. In fact, all self-

Table 1

Welding transformers	*No-load voltage, v.*	*Welding current (25 v.), amp.*	*Average distance between carbons, mm.*
P	42	110	1.5
	42	180	2.9
	42	190	2.8
	42	220	4
C	45	125	4.7
AS	49.5	125	5.38
Constant voltage + resistance	38	120	2.88
	46	120	4.14
	46	150	4.68
	53	120	6.05
Constant voltage + reactance	38	120	3.38
	46	120	5.6
	46	150	5.63
	53	120	7.44
AL	58	110	7.65
CL	64	160	9.15
	64	200	9.2
	64	250	9
	68	29	7.05
	72	52	8.4
	74	90	9
O	73	120	10
SO	80	120	12.1
SE	78	120	12.2
SA	82	120	13.9
AR	85	115	14.8

regulating welding transformers are similar to a constant voltage transformer with a resistance and a reactance in series, of values depending on the efficiency and the power factor.

Although this test has been specially devised for a.-c. current (in France 80% of the welding machines used are welding transformers), it can also be performed with d.-c. machines, but results obtained on a. c. and d. c. cannot be compared. As stated previously, on d.-c current, the shape of the two carbons does not remain the same during the test, the positive carbon being cup shaped and the negative one cone shaped.

Table 2 gives results obtained with a d.-c. self-regulating generator and shows very well the influence of an additional inductance on the stability. In this particular type of generator, the inductance is actually a mutual inductance having two coils. One coil is in series with the field of the machine, the other in series with the commutator, so that a variation of the welding current gives a corresponding variation of the field, this in turn stabilizing the welding current. If, however, one of the coils is reversed, the machine gives a worse performance than when the coils are disconnected.

The table gives results for different no-load voltage and different currents with the mutual inductance reversed, properly connected or disconnected. It is seen from these results that the average distance between the carbons increases with the no-load voltage. The stability is best when the mutual inductance is

Table 2

No-load voltage, v.	*Mutual inductance*	*Welding current (25 v.), amp.*	*Average distance between carbons, mm.*
45	Reversed	80	0.8
45	Suppressed	80	1.61
45	Direct	80	2.43
45	Reversed	150	1
45	Suppressed	150	1.8
45	Direct	150	2.49
55	Reversed	150	3.29
55	Suppressed	150	4.25
55	Direct	150	5.49
60	Reversed	150	3.29
60	Suppressed	150	5.05
60	Direct	150	6.24
70	Reversed	150	7.06
70	Suppressed	150	8.92
70	Direct	150	8.37
70	Reversed	200	7.76
70	Suppressed	200	8.97
70	Direct	200	9.85

properly connected and worst when it is reversed; results obtained without using the mutual inductance being between these two.

A conclusion common for both d. c. or a. c. is that the "setting" is important. One can define a stability figure from this test only by referring to the welding current. This is according to practice, for it is generally known that with the same no-load voltage, it is easier to strike and sustain an arc when the welding current is higher.

It should also be kept in mind that the quality and the size of the carbons must be specified, failing this, the results should always be compared with those obtained from a known machine.

Stability Value

The higher the value, the greater the stability. The minimum accepted is an average of 1 mm. (.04"), with no figure less than 0.8 mm. If this is not obtained after five tests, the number of tests is increased in order to have at least five values greater than 1. If this is not obtained with ten tests, the welding machine is considered as having no welding value.

CONCLUSIONS

This kind of test is now in use in France. The Committee realizes that it is not a perfect answer to the problem of stability measurement, but it is worth trying in order to determine if it should be definitely accepted, or modified, or abandoned. Although not a precision test, it has the advantage of being simple, easy to perform in any laboratory and gives results comparable with those obtained from an actual weld by a good welder.

Should the Guided-Bend Test Be Modified?

Discussion by W. A. Miller

The fishing had not been good, so I dug up the August issue of THE WELDING JOURNAL with the idea of finishing out the day by fortifying my meager knowledge of welding.

AN UNINVITED GUEST

On page 758, I found your invitation to discussion by Technical Committees, Welding Engineers, regulatory bodies and industry. I rebelled at the thought that such as I, who falls into none of the categories, should have been scratched from your invitation list. Nonetheless, I turned to page 755 and found there an inspirational article titled, "Should Human Beings Be Modified to Properly Use the Guided-Bend Test?" and its sequel, "The Misuse of the Guided-Bend Test and Its Effect on Codes."

As I read along, all the fiendish inheritance of my forefathers (most people have only one father) rose to the surface and I could not bring myself to forego the chance to satiate my pent-up desires to:

1. crash a party and wind up either in jail or in print;
2. submit to an Editor a manuscript that would be a nightmare to his trained soul;
3. talk back to a Vice-President at a sufficiently safe distance (it is presumed that the V.P's endorsement of Mr. Stringham's article expresses the V.P's convictions);
4. drive an avid reader to distraction by not coming directly and quickly to the meat of the discussion.

I could go on with the list, but suffice it to say that it had now become apparent that the invited guests had been selected with foresight in receiving comments which would give evidence of reverence for and rational treatment of the subject. Hence, I raise my first objection here by proclaiming that the subject should receive some irrational treatment because erudite discussion is beyond my comprehension.

Due, I presume, to the usual editing, it would appear that considerable was deleted from the V.P's remarks. So, it is well that we renew here what formed the groundwork for the subsequent remarks and the sequence of discussion. The gist of this seemed to be a burst of the old rah! rah! spirit to get everybody on the same side of the table. Next, there was some semblance of an agreement that, since the fundamental basis on which business was founded was to make money, the lowest quality weld which would meet the service requirements for which the weld is intended should be the cheapest.

It even seemed to me that some derisive voice in the background expressed the opinion that to make the most money, the cheapest weld, irrespective of service conditions, should be used. After further coagulation, it appears that everyone had enough sense to realize that what was best for one was best for all, and that there should be a combined effort to work for a common end: i.e., make money even if it inadvertently entailed the advancement of welding.

It is hard to conceive what transpired between the aforementioned get-together and the appearance of this statement, "The only trouble . . . is they do not act as if they were on the same side of the table." By all the rules that are sacred in *Woolley's Handbook*, I have neglected to say who was on the side of the table at the time the table was first mentioned. The V.P's list of invited guests included the consumer, fabricator, insurer, members of Industrial Code Commissions, teachers or students of welding, welding operators and welding equipment manufacturers. It seems rather unsociable not to have invited others, such as the design engineer and the steel-maker, to the festivities.

UTOPIA

Of these, it would seem those most likely to be conducting business for the purpose of making money would be the consumer, fabricator, insurer and welding equipment manufacturer. As the V.P. said, ". . . need I say, 'Why?' " the others are probably not in business for making money. In human relationships there seem to be a few fundamentals which still survive. Among these is the law of self-preservation and another dealing with part of the subject matter of calculus; something about limits, and infinitesimals approaching zero. Of course, this digression should not permit us to wander away from making an analysis of what each on one side of the table wants.

The Consumer: What does he *really* want? He wants equipment that will last forever, do everything

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The paper by L. K. Stringham was published in the August 1949 issue of THE WELDING JOURNAL.

he conceived he wanted it to do, do even things he has not realized he wants it to do; and he wants to get it for practically nothing. In fact Utopia will be here when he can get it for only the freight cost and then he can petition the government to reduce the freight rates.

The Fabricator: What would Utopia be to him? No sales force, orders pouring in as fast as he can handle them, no worry about competition, materials of construction free of charge, no customer complaints, high prices, low manufacturing costs and big profits.

The Insurer: What of him? The role of the insurance company is not completely clear in making money out of welding. However, the ideal situation would be to insure thousands of pieces of equipment that never gave trouble and to do this without acquisition costs for obtaining the business, or subsequent costs for inspection and claim adjustments. With such a condition and no reduction in present premium costs for direct damage, consequential, outage and other forms of coverage, the maximum dollar yield would be realized as the cost of conducting business approached zero as a limit. In a practical way, an insurance carrier does not particularly care how equipment is manufactured as long as there is statistical evidence to establish the accident frequency and the average loss per accident. Along with this must be the ability to insure sufficient (numerically) equipment to obtain a proper spread, and a few other allied data that leads to the positive conclusion that there will be more wins than losses, dollar-wise. Armed with that data, premium rates can be established to make a winning combination for the insurer. I used the word "equipment" to describe what is to be insured. Actually, the company insures an "object," and if you do not think there is a difference between your conception of a tank and an object, read the policy definition of "object."

The Welding Equipment Manufacturer: Last, but not least! What a day! There will be no means other than welding for joining everything, of metal, plastic, wood; everything from ash to zirconium. Welding will be so easy that everyone will be proficient in the art and science. There will be two welding machines in every garage (home garage, that is). Every year the sales manager will have to boost the quota above the preceding year and at once write his speech in advance telling the sales force that their accomplishments exceeded his foregone conclusion that the quota would be met.

To be sure, everybody is on the same side of the table. If they do not act as if they were, why not honestly admit that each one is shooting at a different target? Further, if any should miss the target, why immediately indict, try and sentence the first available person or thing that makes a convenient scapegoat?

TESTING THE MATERIAL

Turning now to the data presented by the author and some of his conclusions in which we are supposed to concur. We were led to believe that a thorough engineering analysis would be made. It is unfortunate that the analysis was not completely divulged. Probably this lack of completeness was a limitation of presentation time, but this sort of briefing without caution notes often does a great dis-service in promoting the development of welding and getting Codes changed. Because no signs were posted, we must assume that the preparation of the test pieces and the testing were chosen to substantiate a preconceived position.

For example, "The lower tensile strength plates were not used because it was impractical to make a sound weld which had less than 65,000 psi. tensile strength in the as-welded condition." What is impractical about meeting that condition? Is it to perpetuate the oft repeated or insinuated assertion that the plate always fails and that no insurance company ever paid a loss because of a poor weld? Is it because the electrode manufacturers will not or cannot produce an electrode to match plate of the various ranges covered by the A.S.-T.M. specifications and made by the steel mills? Is it because the making of such welds would have proved the feasibility of the guided-bend test?

The use of the higher and highest strength materials naturally took the test results in the right direction to lend credence to the preconceived conclusion. We are told that failure was "not because of the operator, electrode or steel being used, but it failed because the guided-bend test is an impractical soundness test when welding on plate having a tensile strength greater than 70,000 psi." All right, I will be magnanimous and give the operator, electrode and welding technique the full benefits of any doubt. Still, did the specimens fail because of the test media?

No statement is made to identify the steel; whether it was alloy, carbon steel, rimmed, fully killed, etc. At least if we were not to be fully informed about a lot of essential items, why were we not told that the steel in the unwelded condition had the physical properties to pass the guided-bend test?

If the plate manufacturer was not required to produce plate with a bend and homogeneity test requirement equal to, or greater than, that represented by the guided-bend test, then I agree it is unfair to expect the weld to be better than the plate alone. However, if the plate alone could pass the test, then the weld should stand the same test. Under the latter circumstances, there is no legitimate complaint against the Code requirements. In the former instance there is ample substantiation that the guided-bend test was misused and misapplied, and very little justification for the statement that the test is impractical.

Allied with the above comments is the important consideration that tensile strength alone may be a very poor criterion of the suitability of steel for use in pressure vessels. Ductility, fatigue strength, creep strength and numerous other factors can be and often are of greater significance than tensile strength.

It is pointed out that, "...there is an abrupt change in tensile strength at the fusion zone if the plate and weld strength are different." The choice of electrode, plate and other procedure variables should not be prop-

erly charged against the guided-bend test. It could be that the fabricator, operator and a few others who elect to control are delinquent. On what logical ground do the electrode manufacturer and the fabricator ask to be excused from performance at the weld that is not tolerated at any other point in the base plate with respect to ductility, grain structure, hardness, etc.?

LIMITATIONS OF THE TEST

The preparation of a sample with lack of fusion at the neutral axis and the case of the specimen with lack of fusion at the root both successfully passing the guided-bend test are mentioned, supposedly to disprove the value of the testing medium. The same results could have been obtained otherwise. In the first instance, a small hole could have been drilled through the neutral axis of a solid plate specimen and the plate would have passed the test as successfully as did the weld. Technically, the test did not detect unsoundness under those particular conditions. So, micrometers do not measure to a small fraction of a wave length of red light; the micrometers are not a perfect measuring tool and all should be discarded. That also goes for the bulk of our measuring equipment since most of it is imperfect. However, micrometers are practical measuring tools, and so are the bend test and the old nick-break test.

In the second instance, the root-bend test would certainly have detected the lack of root fusion on about the same basis as the notch specimens which were prepared and tested. If the author's notch specimen had been placed with the notch on the inside of the bend and tested as was the specimen with deficient root fusion, the conclusions drawn would not have been so odious a reflection on the guided-bend test.

For certain classes of work, there are welding standards (API 12-c, for example) which permit welded joints having lack of fusion at the neutral axis. Even the author's suggestion for a good soundness test seems to have the familiar ring of the note forming a part of Paragraph Q-209:

"NOTE: For welding under the requirements of Par U-69 and U-70 the following results are required:

"The specimen shall be considered to have passed if (1) no cracks or other open defect exceeding $^1/_8$-in., measured in any direction, is present in the weld metal or between the weld and the base material after the bending or (2) the specimen has cracked or fractured and the fractured surface shows complete penetration through the entire thickness of the weld, and the absence of slag inclusions and porosity to the extent that there are no gas pockets or slag inclusions exceeding $^1/_{16}$ in. in greatest dimension and the sum of the greatest dimensions of all such defects in any square inch of weld metal area does not exceed $^3/_8$ in. (If necessary, the specimen shall be broken apart to permit examination of the fracture.)"

CHANGING CODES

Codes are not perfect and always need changing with the times. The real disagreement comes when trying to get a group to agree on the nature of the changes, the proper time for changing, the extent of the changes and the rapidity with which the changes should be made. Within the limits of my experience, codes and laws are always preventing me from doing what I want to do when I feel like doing it. In the shop the same situation prevails; why can not everybody be willing to accept "standard commercial welding," or "standard shop practice."

The definition of both terms means welding done any way the shop chooses, at any point they choose and subject to change of method at any time. If the Codes have impeded progress it might be almost fair to concede that they have merely retarded the rate of change to a pace borne out by accumulated experience and all connected with welding might awake one day to find out that change at a faster pace might well have permanently stunted the industry's growth.

The promulgation of Codes often gives many of us a chuckle at the naïvete of those who formulate the Codes. For example, this quotation is taken from Page 1, Section IX, of the A.S.M.E. Boiler Construction Code:

"These rules are intended to apply...to those.... metals which in their unwelded condition will meet the requirements of the guided-bend test prescribed herein. *It is assumed that the manufacturer has an organization familiar with the various welding codes* and capable of designing, engineering and supervising welded construction."

The words *italicized* do not appear thus at the original source. The inclusion of such a statement in a preface shows the wishful thinking which often finds its way into codes. Would fabricators who agree to perform work to Code requirements find themselves in the dilemmas I have so often found them in if they were really familiar with the Codes? Why should anyone expect a shop to add to its expenses by paying the cost of having personnel capable of designing, engineering and supervising welded construction?

SOME PRACTICAL CONSIDERATIONS

Certainly, the practical approach is to hire a "good welder" and turn the job over to him. Going back to the days when I did some welding, I recall what I did when the boss threw a job at me and told me to get it out P.D.Q. Before starting to weld, I always pondered whether I should select an all-purpose rod somewhat on the order of an E-6020, or a mild steel core with a feldspar-iron oxide flux (NOTE: the old-time welders had rods classified long before the A.S.T.M. and others codified all this). Next was a careful consideration of the equilibrium conditions which would exist between the molten metal and the slag during the course of depositing the weld metal, together with thought on the iron-oxide (FeO) content in the slag to the total oxygen content of the deposit. Beside investigating the electrode to determine if the slag deposit would be acid or basic, there was always the effort made to determine the

nature of the steel; at least to the extent of whether it was rimmed, fully killed or oxygen-bearing which might affect its impact value. Dry-and wet-bulb temperature readings were taken and the humidity conditions thoroughly explored to ascertain if moisture in the coating of an E-6020 electrode would cause weld porosity or whether the weld metal would absorb hydrogen with the possibility of hydrogen embrittlement. These of course are only a few of the factors that will be mentioned because the secrets of the old masters should not be fully revealed.

Next, the shape of the weld groove was analyzed to see that welding was done so as to get the optimum weld with the minimum of deposit. Naturally shrinkage, warping, locked-up thermal stresses and all the other important factors were subjected to scrutiny. Until all these matters had been disposed of, no welding was done. Since that time tremendous advancements have been made and my observation of the up-to-date operator would take too much time to record. In general, I hear a lot about the high wages paid to operators and all that sort of thing. Invariably my reaction is the same: if an operator were the combination of artist, workman, engineer and metallurgist the average shop would like to hire, then he would be a blankety-blank fool to work for a welder's wages when the world seeks his sort so badly at a price he can name.

THE OPERATOR

These remarks should also explain why the author should not have been so surprised that 2 out of 35 operators passed the test in the illustration he cited. There is only one conclusion to be drawn on their ability to pass the test: namely, they made a thorough preliminary examination such as an old master-welder would have done before proceeding with the job. If the results of their cogitation had led them to the conclusion that the job could not be done, they would have walked away without even attempting to make a test weld.

I believe it is the consensus that welding is possible on the basis we now know because there is a combination of variables which can be selected for any given situation which will result in an acceptable weld. Thus, each time the given situation arises, combining the identical variables and repeating each and every process and operation in exact sequence and using the proved technique produces the same precision in end-result. The author admits two operators successfully passed the test. Thereby it was proved that the weld could be made. If we are to continue to have confidence in welding, we can only conclude that any other of the 33 failing the test could pass it by duplicating in every detail that which was done by the two successful operators. The example is not a legitimate indictment of the bend test.

If the example was advanced as evidence of high cost, other avenues of analysis should be followed to see if the stated conclusion is warranted. Was the weld too good for the service conditions? If it was, who specified the caliber of the work? If specifications were too rigid, blame the person responsible; not the bend test.

Was the base plate too good for the service conditions? Then someone ran up the cost by specifying too expensive material.

If the plate is properly selected for service conditions, then the weld should be equally good as the plate.

If the agreement to do work to specifications left no misunderstanding on what was to be done, no one should have been cheated.

If the contractor really understood what he had undertaken to weld and had not assured himself of the feasibility of doing the work, should the quality of the work be degraded sufficiently to maintain the exact margin of profit he included in his bid?

CODES

We are told many codes are obsolete. No clue has been given as to how many is "many." In fact, the very use of the word "code" without a statement of defining limits, erects a barrier to clearing some of the confusion. If we include the industry and trade association standards which have been prepared as general guides for those who wish to adopt an established pattern, the engineering specifications that are conceived and prepared for each job, and those rules which are promulgated to have a legal or quasi-legal status, then "many" may be numerically great.

Of all of these, the only ones which might be considered as possible legitimate targets for impeding progress in the use and application of welding would be those rules which have legal standing and which may not be disregarded with impunity. Even that classification would be an impediment only if it deteriorated to a condition of statism and the rules were not modified from time to time to keep pace with developments. It is generally true that these Codes provide media for considering individual cases, granting variations from the rules, and recognizing "hardship" in specific instances.

Those "codes" not having a legal status do not throttle the user of welding because following the requirements is a matter of agreement between the principals directly involved. Any unfair requirement in the standards can be modified at will without reference to the standards-formulating body.

In so far as codes are concerned, if there are "many" it would have been so helpful, not only to learn how great was their number, but more particularly, the percentages of the total volume of work which is done or available to be done under each code. If the bulk of the available work comes under the requirements of a relatively few codes and those few were reasonably good, the balance of the work to be done under unreasonable codes would be so little that welding progress would not be retarded to any greater extent than the desire to make money by contracting to do work under unreasonable requirements. It is evident that if no one was willing to do work by bad standards, the standards would either be remedied soon or become extinct, and under

both circumstances welding progress would not be retarded enough to notice the deceleration.

I wonder if the Codes are really to blame for all the ills that are attributed to them, especially the guided-bend test, or is it that lack of familiarity with the Codes, by honest ignorance or deliberate choice, is the more important consideration; completely ignoring the old adage that money is the root of all evil and there are multitudes who want more root.

It would be interesting to peruse the results of a survey giving data on such items as the following:

(*a*) The number of shops engaged in manufacturing vessels, piping, etc.

(*b*) How many contract to do work to Code requirements.

(*c*) Of those who work to Codes: (1) What percentage have copies of the Codes available for use and how many copies; (2) An honest count of how many in each organization have read the Codes; (3) Of those who have read the Codes, how many have really *studied* them?

(*d*) How many have a copy of the A.W.S. *Welding Handbook* and of those who have it, how many have read and studied the chapter on Welding Qualifications (let alone the rest of the book)?

(*e*) A breakdown of the shops as to size and the number in each group who really feel the bend test is impeding their progress.

The result of one survey shows that the ones making the most complaint are those who just do not know their codes; who want to do every job which can be done by anyone else, but who do not want to be burdened with the chore and expense of providing the equipment, personnel and development expenses involved to properly do the jobs.

SIMPLICITY OF WELDING

There has been a great deal done to bolster the idea that welding is so simple that the degree of weld quality can be controlled so exactly that the operator can easily make a weld to any stated percentage of goodness so that the weld need be no better than the actual service conditions. Further, achieving the exact lowest percentage reduces the weld cost in direct proportion. I presume I am the only one who has ever had the experience of being involved in numerous cases where trying to make a cheap weld to just exactly get by resulted in weld costs greatly in excess of making a good weld.

It would be a great comfort to hear that at least one other person has knowledge of a similar occurrence, and thus relieve me of the burden of being the repository for a unique experience. After all these years it is a shame that the corpse should still be condemned to walk the streets because no one will claim it and give it decent burial! Until now, it seemed years ago since last I had heard the tune, but the sound of the melody turned back the years. Codes were young and small then. The boiler and tank industry had been as unfettered as a wild horse and each member knew that cut-throating and sudden retirement from competition were synonymous. In fact, it had gotten so bad that even the hardiest of them were looking for protection and trying to make popular the idea that what was good for one was good for all. The shmoo had not made its appearance, but another animal named a "Code" proved to be their savior as a rallying post.

CODE EVILS

About that time I also began to take my proper place in society and learn that association with my fellowman was not only beneficial for me, but it was my duty to benefit the other fellow even if I forced it on him. Thus I began to attend the meetings of the Boiler and Tank Manufacturers' Association. First in one city, then in another, and another, until I had made the rounds. And what I learned about that insect, the Code!

There was great disillusionment. Each shop seemed to have gotten the convenient impression that the Code had been invented for the specific purpose of restricting the other fellow but permitting his particular shop to do what it pleased. What could be nicer for business? Your competitors were to have their hands tied and you could be free to swing anyway you wanted. Boy, could you go to town and prove that the purpose of business was to make money! Instead of all this, was the eventual realization that the battle was to be continued with your hands as equally tied as your opponent's.

Something ought to be done about it and there developed a vociferous tirade against the Code. It was hamstringing the industry; the customer was being given a beating; it was raising costs. So it was. The "good old days" had put a premium on doing the lowest class work possible and the Code had come along and placed a floor to prevent design and workmanship from sinking below a certain level. In the rush to flog the Code, no one said a thing about the consumer getting a better buy for his money and not having to depend on a fabricator's "secret formulas" for calculating the strength of the structure, etc. Not a word was said about the benefits to the industry in not having to wade through specifications which detailed every step of its activity in building the equipment. The specifications were as varied as the persons who wrote them and virtually were jousts between the buyer and seller to see who could out-maneuver the other. The criterion of a good business deal was not how much was made during the course of a transaction, but how badly you could "stick" the other fellow, and the battle cry was "Buyer Beware." Yes, the Code was the source of all the trouble!

I still recall, in particular, the president of the Boiler Manufacturers' Association of one of the large midwestern cities. During his tenure of office, the evils of the Code were so well ventilated and exposed to scrutiny that I have heard no new arguments since that time some 20 years ago. While he wailed about how the

Code was putting him out of business and would do likewise to others if they did not join the crusade against the Code, his business improved. Today he is still in business; business is better than ever for him; and he has attended the funeral of a good many of his local competitors who believed the Code was good.

I expect some day, not too far hence, to pay him a visit and I feel certain that I can "inadvertently on purpose" make just the right remark so that any of you with wire recorders within 450 miles of his shop can get a first-hand review of ancient history as it pertains to the evils of the Code!

The author chose to quote excerpts from the A.W.S. standards and to offer suggestions for a good soundness test as an improvement on the existing standard. Let me also quote from the A.W.S. publications and let us see how far behind the times these armchair engineers really are and how little they realize what the score is. For those who now might have obtained an inclination to get acquainted with standards and codes, let us turn to Chapter 29 of the 1942 A.W.S. *Welding Handbook*.

First this paragraph from the Foreword: "The tests required for a welding operator are included in the investigation of a welding procedure because there have been many instances wherein failure to obtain results have been attributed to the inability of the operator when the difficulty lay in the fundamentals of the procedure..."

In the light of this statement, look back at the author's comments about busting-out of good operators; the case of the 33 out of 35 who failed; the statement made above about the shops and contractors who want to hire operators made to order and save training costs; what the various groups really want when they all get on the same side of the table; the author's misuse of the bend test and the data obtained thus to prove that the test could be misused. Then soberly decide if the fault lies with the testing medium, the numerical values used to evaluate results, the standards as written, or if the real fault is the misuse of a good medium. For my money, if such consideration as this in a standard is armchair engineering, let us have more armchairs.

Let us continue with Section 109, Test Results Required; Note I: "The values as set forth shall apply where no Code is in effect, or where an agreement to use other values have not been made between the purchaser and vendor."

(Now, who is stopping which from doing what and increasing the cost; the standard or the purchaser and vendor?)

Note III: "The test results are not likely to be attained with the metal-arc process when using bare or lightly coated electrodes. For such processes, it is recommended that the governing Code adopt the following requirements for test results."

The values have been reduced to 85% of the tensile strength of the base material; elongation reduced to 10% minimum; and the requirements for root-, face- and side-bend are as previously quoted from the A.S.M.E. Code for Paragraphs U-69 and U-70 service and paraphrased by the author in his suggestion. Again, if things like these are armchair engineering, let us have more armchairs.

There are more quotations which could be made but it would bring so much more comfort to the oppressed if they were to seek out those things by direct investigation rather than continue to bemoan their plight; and papers such as the author's are not the right kind of aspirin for a welditis headache.

I would like to find out how sincere everybody really is about being on the same side of the table and willing to demonstrate the intensity of their incentive to work together toward a common goal of advancing the use, art and science of welding.

The author would retain the guided-bend test simply because it is so widely used and because most concerns doing Code work have bend-test equipment. If the test is not much good and it is adding so much to welding costs, what economic consideration is there for retaining it and the equipment with any more justification than exists for hanging on to other obsolete machines? However, let us not discard the jig until a lot of the big items of expense have had attention first.

COSTS

If cost is important, why do we tolerate a system that requires each shop to prepare and test a welding procedure at a cost in man power and materials which probably would make the highest paid movie star's income look puny by comparison? Why should we permit a setup which gives the bend test so many unneeded opportunities to bust-out good operators; along with the thousands of dollars again involved with man-hours and materials in preparing test plates? It can be done by cooperation between various groups. The author's paper implies that the electrode and welding equipment manufacturers have a lot of know-how technically and, we hope, cooperatively. They also seem to be among those oppressed. The Code and standard makers have certainly been brought onto the scene, as well as the fabricator, and I shall tentatively nominate an innocent bystander, the National Board, to join the fray. This action on my part without consulting them will only add one more to many previous provocations for rescinding my commission.

The scheme is merely outlined below with broad pencil strokes so that the detailing will leave plenty of room for participation by all and the quantity of glory in the project is great enough so that everyone will receive a large share.

1. Make a survey to reveal the tonnage of the various A.S.T.M. Spec. steels used in constructing A.S.M.E. vessels.
2. Determine the steel most used, tonnage-wise.
3. Let all electrode manufacturers get together and prepare a welding procedure for that grade of steel.
4. After preparation of the procedure, the electrode manufacturers shall test the procedure and an authorized inspector shall witness all preparation and testing

of the test plates as is now done at each individual shop.

5. Upon satisfactory completion of the procedure qualification, the written procedure and signed copies of the test results will be filed with the National Board.

6. Copies of the procedure and test results would then be procurable from the National Board, at a charge to be announced, by any shop desiring to use the procedure, provided:

(*a*) the shop made application to the N. B.

(*b*) investigation satisfied the N. B. and Code, that equipment, personnel and other facilities were adequate for scope of work the shop has specified it desires to do.

7. After obtaining procedures and results, the shop would qualify its operators under N. B. or recognized testing laboratory supervision.

8. For all applicants that are not busted-out, the shop would file with the N. B. signed copies of operator qualification-test results, together with a filing fee.

9. The N. B. would issue a service log book to the operator in which the shop would make entries of the employment date of the operator and the signature of the operator's supervisor; another column would be provided for a date entry when the operator terminates his service with the shop. The book would contain the operator's picture and signature under a durable, transparent plastic covering, so fastened in place that its removal would mutilate the picture and signature enough to preclude use of the identification by anyone but the rightful owner. (The book should be of welded construction.)

10. When seeking re-employment, the book would be presented by the operator to the prospective employer. If the last entry showed the operator had not welded for over three months, the new employer would have to requalify the operator and file test records with the N. B.

11. The log book would be renewed at least every two years and it would be the operator's responsibility to take care of the renewal either directly or through the shop organization.

This still leaves things open for the rugged-individual shop to do as it does at present in preparing and testing procedures if it believes that is best. It does not disturb the status quo for those shops who even prefer to go to the extreme extent of manufacturing their own electrodes! If someone sincerely means to help the operator, help the shop with limited technical knowledge and boost the welding industry by cutting red tape, lost motion, unnecessary costs and elimination of this duplication of testing without decreasing the caliber of welding, then the idea advanced is worth acting on.

In advance, I warn those who have already cooked up objections to the scheme since reading it, that I have already mentioned that fellow who 20 years ago had all the answers. There will be the magnitude of the task of keeping track of the operators. How about the system used by the seamen in taking care of crew members who sail the seven seas? There will be the squawk of the established shop that it will be put in competition with the fellow who has only a one-car garage, a welding machine and no overhead. Why go on? The idea is possible and it is practical but certainly the basic approach leading to success will be for those involved to start by looking for reasons why it can be done rather than excuses for not doing it.

The Piping Contractors' Association has already started the ball rolling. When the idea started in the Chicago area the greatest obstacle in overcoming antagonism was convincing the individual that someone was not going to increase his competitive advantage under the new plan.

The scheme has, so far, only high-lighted what the welding equipment industry and the N. B. were to do. What of the code makers? Of course, they will have to modify their rules where needed to integrate Code provisions to fit into the general plan. What are the chances that they will do so? Just to make the race very interesting, shall I wager that the code makers will probably beat the welding-procedure makers to the post by a length, however small. If I lose, my bet will be paid in full at the proper time; namely, I will extinguish forever any desire on my part to ever drag a string of tripe like this across the pages of THE WELDING JOURNAL and before the eyes of its readers.

After the plan gets working, the system of fees and charges will defray the expenses of operation and gradually provide funds for successively preparing procedures to weld not only the more used grades of carbon steel, but such metals as aluminum, copper, some of the alloy steels and the more commonly used grades of stainless steel. This Marshall Plan for the underprivileged in the welding industry will require that the individual must still help himself, but the health provisions of the plan will make it possible for the shops to obtain the services of the best qualified consultants on the subject.

There will also be a number of fringe benefits derived from the plan. The trade schools teaching welding would be provided with a really good training tool compared to those many have now, and the cost of industry training could be considerably reduced. We have many good, solid youngsters who are investing their money and time to become craftsmen. They deserve the boost of receiving a log book as a diploma for a graduation examination conducted by an impartial examiner, and a half-way decent chance to land their first job for breaking into industry.

The labor unions also carry on training programs directly or sponsor courses in many of the city schools. They often supply equipment and contribute money to insure good courses of training in these schools. A little planned cooperation between industry and the unions would go a long way toward reducing welding costs.

As has been said previously, why go fishing for small fry in the form of bend tests for saving money when the big fish are waiting to be hooked?

If the Editor fears that future issues of the JOURNAL will be somewhat barren because discussions on the bend test will be eliminated by adoption of the plan, may I suggest that someone prepare specimens, test them and

write an article to prove that the present nondestructive tests in the Code do not detect lack of soundness under all conditions; also that they do not detect all forms of lack of soundness under some conditions. Such Code testing costs money. Those expenses add to the cost of the finished work. Therefore, x-ray is impractical and should be eliminated. Q.E.D.

If no one has in mind a likely candidate with the proper qualification, I shall be glad to name one—need I say, "Whom?"

IN CONCLUSION

The sun is out again. In case no one remembers, I interrupted my fishing to write this. If I have not proved my disqualifications by now for giving this subject irrational treatment, it is too late to try further. The fish are biting and I must be on my way. My neck is thick, tough and it has been stuck out a good many times, in addition to the present instance; do not hesitate to take a healthy whack at it when the inspiration strikes you, and I, in turn, wait for the fish to strike.

So, with malice toward none, my friends and my enemies (and you are one or the other by now if you have read these words to the bitter end), I say "Auf wiedersehen," and do come up to visit as soon as you can recover from your present attack of guided benditis—there is so much more on the subject that requires attention.

Discussion by Perry C. Arnold

I concur with Mr. Stringham's recommendations that it should be modified.

I think Mr. Stringham has very ably set forth in writing what many of us have been thinking and discussing for some time. My reason for saying this is, that only a year ago, we had quite a discussion with the A.S.M.E. Code Clad Committee concerning the free-bend test of stainless clad material. Since our discussions and arguments on these tests, the Code Committee has revised Code Case 896 so that the bend could be made in such a fashion that the two different strength materials were stretched an equal amount.

I would like to even go further than Mr. Stringham has, in recommending modification of the guided-bend test. In fact, I would like to recommend that the qualification test itself be revised so that one of several joint designs could be used on a test plate.

We are steel-plate fabricators applying the welding process for the joining of plate edges together. Approximately 90 to 95% of our welds are made in double-vee type groove welded from both sides. The welding of this type of joint is much different than welding a test plate of a single-vee groove design and a backing-up strip. In other words, we feel that when we qualify our welding operators on the single-vee type groove with a backing-up strip, that we are not checking their ability to weld double-vee type grooves where the seam is always back-chipped and readily welded from both sides. We would also like to think that giving our welding operators a qualification test would enable us to teach the operators the correct procedure for the welding to be followed on the work that they are subsequently going to do. At the present time, the reverse is true. The operator takes a test on a single-vee groove backed-up joint, and then immediately goes to work welding up mostly double-vee type joints.

We think it advisable that an alternate be added to the operator's qualification test so that double-vee type groove plates could be used instead of the single-vee.

Another point brought out by Mr. Stringham which I would also like to augment is that nothing is said in the qualification procedure concerning the time limit on the test plates. It is a well-recognized fact that if an operator's qualification test plates are welded, machined and tested the same day, that many of the specimens will break in half when they are bent and the break show good, clean weld metal. The theory at the present time is that the weld contains a sufficient amount of hydrogen to embrittle the metal. An operator should not be disqualified if this occurs.

I think it imperative that the standard qualification procedure be revised to include the things that we are learning in welding as we go along. To my knowledge, there has not been any revision since 1941, and I personally think that we have learned a lot since that time.

I shall be very glad to render any aid that I might give toward bringing around some revisions in the near future.

Discussion by F. Lang

SUGGESTIONS FOR MODIFYING THE GUIDED-BEND TEST

L. K. Stringham's suggestion of modifying the guided-bend test could be accomplished by adding two more tests to determine an operator's qualification, and by setting a limit on the application of the guided-bend test itself.

Bend tests are used to determine and investigate the toughness of a material and may take many forms. However, it is the ductility of the material, with or without welding, that is studied. When welding enters the picture it brings with it several other factors which must also be considered.

First of all, a sound weld must be produced or the investigations are impracticable. For that reason the chief factors for which the operator is responsible must be considered almost without reference to any bend test.

These responsibilities on the part of the operator are:

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1. Selection of proper electrode
2. Influence of current (d. c. or a. c.)
3. Polarity
4. Strength of current
5. Arc voltage
6. Travel speed
7. Arc stability
8. Penetration
9. Weld free of undercut, cracks and porosity

These responsibilities and the weldability of the material should be considered along with the other factors which influence the capacity of sound and uncracked welded joints to deform without failure under any testing conditions.

These factors are:

(*a*) Composition of the base metal
(*b*) Rolling direction
(*c*) Deoxidation practice
(*d*) Plate grain size
(*e*) Skin due to rolling
(*f*) Resultant macro- and microstructure
(*g*) Magnitude of applied stress
(*h*) Transition temperature

By checking points 1 to 9 we know how the weld metal should be fused to the base metal, but we do not know how the welded joint will react to any sort of test. Mr. Stringham brought this out quite clearly in his article.

Bend tests should be considered only as guides to the weldability of a metal. The flexibility of the test specimen is all that can be ascertained with a bend angle. The genuine deformation of the weld metal can be determined by measurements of its ductility. One of the most important factors involved in any bend test is the relation of the tensile strength of the weld to the tensile strength of the parent metal, as Mr. Stringham has pointed out.

However, an approximate ratio of the tensile strength of the weld metal to the tensile strength of the parent metal can be used since ideal conditions do not exist in parent metal due to defects and flaws.

In the case of groove or fillet welds the best test for qualifying an operator is a tensile test since the fracture will occur at the weak point whether it is in the weld or parent metal. Failure in the weld metal can be attributed to the operator under one or more of the responsibilities which have been listed. Failure in the parent metal, including the heat-affected zone cannot be blamed on the operator.

However, mechanical testing is not enough unless the metallurgical aspects of each case are also taken into consideration. The defects listed under point 9 are quite important in inspection. Nondestructive radiography, X-ray and gamma-ray inspections can be applied to welded objects, but it is best in the case of a test plate, to secure a photomacrograph in order to explain the good and bad points to the operator.

In Tentative Standard Qualification Procedure B3.0–41T and Code of Minimum Requirements for Instruction of Welding Operators B2.1–45 there is no provision for this photomacrograph test.

Section V, "Instruction in Welding Theory," Section 506, Topic E—"Weld Characteristics" states: "The instruction in this subject shall be designed to familiarize the student with the characteristics of good welds. The discussion shall include the following topics-

(*a*) Soundness
(*b*) Fusion
(*c*) Penetration
(*d*) Weld contours and dimensions

Section VI—602, "Types of Tests Required," states: "The tests described herein are specially devised tests to determine the student's ability to produce sound welds. For fillet welds the test prescribed is the fillet-weld-soundness-test; for groove welds the tests prescribed are the root- and face-bend tests."

Section 609, "Requirements for Passing Final test," says: "Before a student may be considered as having completed the course, he shall be required to pass all the tests prescribed in this Section in all four positions. The Student's Record Card shall contain a statement of these tests, indicating the welding process, classification of electrode and size of electrode used in each position."

From this it would appear that the bend test should be universal in establishing an operator's qualification, however, that is not true.

In my experience in the instruction and examination of welders in regards to soundness, fusion, penetration and weld contours according to Section 506, I find that a tensile test and a photomacrograph are helpful in determining an operator's qualification. The photomacrograph shows the operator's success or failure in points 1 to 9 as illustrated in Tables 1 and 2.

By cutting a bar from the test plate and grinding and polishing it, fusion and penetration can be seen distinctly. However, defects and flaws in the base metal cannot be distinguished until the section is etched.

The double V-butt joint of test specimens 1 and 2 in Figs. 1 and 2, respectively, were flame cut in a straight direction and the edges to be arc welded were planed. Specimen 1 was welded with a cover bead on each side, while Specimen 2 was filled with a root and topped with a cover bead on each side. Special attention was given to the first pass to insure satisfactory penetration and fusion. The specimens were not chipped in the root, but were carefully cleaned before each step.

Both specimens were subjected to tensile tests and photomacrograph studies.

No significant differences in tensile properties appeared between the specimens, as can be seen from Table 3. Specimen 1 failed in the weld, as could be expected from an examination of the photomacrograph in Fig. 1 which shows a lack of root fusion and heavy segregation. Specimen 2 fractured in the base metal.

Poor welding technique caused the lack of root fusion in Specimen 1. This causes an unsatisfactory weld although there are some satisfactory points to it. Specimen 2 meets all the requirements of a satisfactory weld.

Table 1 Qualification Setup of an Unsatisfactory Weld (Fig. 1)

Responsibilities of trained welding operator	*Judgment of the Welded Joint* — *What is wrong in the welded joint*	*What is satisfactory in the welded joint*
1. Selection of proper electrode		Soundness of the weld metal
2. Influence of current d. c. or a. c.		Fusion to parent metal
3. Polarity		Free of undercut, cracks and porosity
4. Strength of current ←→ No. 4		
5. Arc voltage		
6. Travel speed ←→ No. 6		
7. Arc stability		
8. Penetration ←→ No. 8		
9. Free of undercut, cracks and porosity		
Failed:	In the weld metal because of lack of root fusion	

Table 2 Qualification Setup of a Satisfactory Weld (Fig. 2)

Responsibilities of trained welding operator	*Judgment of the welded joint* — *What is wrong in the welded joint*	*What is satisfactory in the welded joint*
1. Selection of proper electrode		Soundness of the weld metal
2. Influence of current d. c. or a. c.		Fusion to the parent metal
3. Polarity		Root fusion
4. Strength of current		Free of Undercut, Cracks and Porosity
5. Arc voltage		
6. Travel speed		
7. Arc stability		
8. Penetration		
9. Free of undercut, cracks and poro-porosity		
Failed:		In the base metal

When viewing the operator's responsibilities it becomes apparent how many factors must be taken into consideration to prevent ham-stringing him. One simple, but very important, point is that the equipment must be in good condition.

This test was selected because the materials to be arc welded show decidedly different macrostructure. Despite heavy segregation both welders showed satisfactory fusion to the parent metal. However, complete penetration at the root was obtained by a change in technique. Segregation cannot be avoided in certain types of ingots and will remain after rolling and forging so that it appears in small or large amounts in nearly all rolled steels.

This segregation which can be seen in Figs. 1 and 2 will influence the technological and mechanical properties of the steel. It will be more brittle and more susceptible to weld-cracking and porosity. However, in these tests a sound weld was found among such unfavorable conditions in the base metal.

I would like to suggest a change in the qualifications tests of operators as set forth in B3.0-41T. I suggest that tests along the lines which I have laid out would be a closer check on the operator's responsibilities than are the root- and face-bend tests which are influenced by the materials to which they are applied.

During the past ten years a great effort has been made to study the effects of welding on different steels in order to further develop welding engineering. The steels most suitable for welding are now well known, and the operator can now turn out excellent welds without preheat or postheat precautions. This is all the more reason why the accent should be on technique, which includes all these factors which have been enumerated here. It also calls for greater and closer cooperation between all of us who are interested in welding.

Table 3 Test Data from Reduced Tensile Test after Fig. 3

Specimen	*Width mm.*	*Thickness mm.*	*Area mm²*	*Tensile Strength — Tensile force, tons*	*Kg./mm.²*	*State of fracture surface*
No. 1	29.8	9.4	280	13.10	46.80	Sinewy, jagged, mate. Fracture in the weld. Lack of penetration at the root of the weld.
No. 2	29.8	9.4	280	14.28	51.00	Sinewy, jagged, mate. Fracture 1 cm. out of the weld metal

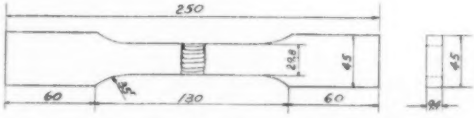

Fig. 3 Test specimen for reduced tensile test (dimensions in ml.)

Fig. 1 Photomacrograph of specimen No. 1 welded with a double V-butt joint

Fig. 2 Photomacrograph of specimen No. 2 welded with a double V-butt joint

Tests performed: (*a*) reduced tensile test and (*b*) metallographic-test (macrostructure).

Discussion by Bela Ronay

In discussing the guided-bend test given in Mr. Stringham's paper in the August 1949 issue of THE WELDING JOURNAL, it appears advisable to review briefly the history of this test.

The guided-bend test, to the best of my knowledge, was originated a good many years ago at the Bureau of Construction and Repair of the Navy Dept. The purpose of this test was to qualify welders in ship construction. It was based on the understanding that the most difficult pass in making a butt joint is the root pass and that another telltale of the welders experience is whether the joint was completed without undercutting. Extensive investigations performed by several Naval activities for evaluating the suitability of the guided-bend test as a means for qualifying welders showed the following: The grade of base metal of the test assembly, plate edge preparation, root spacing and the method of assembling the plates and backing strip must be strictly in accordance with the specifications in order to obtain consistent results.

Correlation of Arcronograms and X-ray examination as means for qualifying welders demonstrated, in addition to the above, the influence of the volume of the root pass deposit as regards the degree of fusion, the depth and the character of the heat-affected zone. This investigation showed conclusively, that guided-root bend specimens will fail, regardless of the apparent soundness of the deposit, unless the volume of weld metal deposited in the root pass is sufficient to affect a proportionate volume of base metal adjacent the root to that degree which renders it ductile enough to participate in the stress obtaining at the root zone by gradually transmitting the stress in the adjacent, unaffected base metal.

The practical meaning of the above is the requirement to deposit two full length, $^{5}/_{32}$-in. diameter E-6010 electrodes (2-in. stub), into the 6-in. length of the root pass of the Navy No. 1 Welder's Qualification test in the vertical. The welder who can hold a steady arc in depositing a bead, but does not have sufficient experience to maintain a steady arc while depositing in the vertical a $^{5}/_{32}$-in. diameter electrode down to a 2-in. stub within a 3-in. length of the root pass, will not develop a well fused joint, and his root-bend specimen will fail. Similar requirements obtain for assemblies other than that used in the above test.

The above investigations were performed using ship grade, low-carbon steel plate stock, in that the test was, at first, intended only to qualify welders in ship welding.

In adapting the guided-bend test for qualifying welders with materials other than mild steel and flat-plate assemblies due consideration was given to joint design and the metallurgical factors involved. Thus, welders qualification test assemblies composed of air-hardening steels which require pre- and postheating to restore the ductility of the fusion zones are so treated in Navy practice before they are fabricated into test specimens. Since the development of the guided-bend test it was used at the U. S. Naval Engineering Experiment Station as a check against the Arcronograph in determining the applicable welding technique in connection with the development of welding procedures for a wide variety of metals used in the fabrication of Naval propulsion equipment. It was found at all times, even with 0.4% carbon–$3^{1}/_{2}$% nickel ship shafting steel that the guided-bend test is applicable to evaluate whether or not a welder learned the applicable welding technique. It is regarded, however, that testing welders qualification coupons fabricated from air-hardening steels, without the application of the required pre- and postheat treatments, is not a profitable venture. On the other hand, substituting mild steel as material for welders qualification test when the material to be welded is an air-hardening steel appears to be a form of self deception in that it defeats the very purpose of the test. Further, there is considerable experience in the fatigue testing of weldments which indicates that the presence of scattered porosity and inclusions is relatively unimportant compared with that of mechanical or metallurgical notches, particularly if the voids are not exposed on the surface of the weld.

In view of the above, abandonment of bend tests for qualifying welders cannot be justified, especially for the untried device as offered by Mr. Stringham. Particularly, as no data are available to correlate performance and the presence of blowholes and inclusions amounting to 5% of the fracture area. Evaluation of the suitability of the weldment on the basis offered by Mr. Stringham would be further handicapped if performance of welders were appraised on basis of the sum of the defect areas without regard to the pattern of the defect distribution.

As regards Mr. Stringham's remarks concerning section 102, the Standard Procedure Qualification Test of the A.W.S. Code, it is agreed that there is room for improvement. Procedure Qualification Testing is another "Navy First" having originated with the Bureau of Ships at the recommendation of the U. S. Naval Engineering Experiment Station. As practiced by the above activity it is a most searching test applied to determine, quantitatively when warranted, the suitability of a welding procedure for the purpose intended. The bend tests given in Section 102 of the A.W.S. Specification for Qualifying Welding Procedures are searching and, when properly applied, indicate definitely whether or not the applicable welding technique was employed. The information obtained from the bend tests is, therefore, an important part of a Procedure Approval test, though, for many types of weldments it is insufficient in itself in that there are other factors which are of com-

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parable importance as regards the suitability of the procedure. Thus, the reasons given for retaining the bend tests for Section 202 are also valid in all particulars for Section 102 of the A.W.S. Specifications for Qualifying Welding Procedures.*

* The opinions given in the above discussion represent the personal views of the writer and are not necessarily the official views of the Navy Dept.

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Weldment Design and Engineering Practice

Fundamentals of the engineering, planning and designing of economical and safe weldments and the necessary follow-through are briefly covered

by Anthony K. Pandjiris

DURING the past 10 years, we have seen the infant industrial tool welding grow into a talented eager youth willing to attack the modern problems which effect every day commerce.

However, this talent lacks the seasoning of elders.

Let us look to the harnessing of one phase of this latent power; the engineering aspect of welding as it relates to the proper method of producing successful weldments. The formulating of engineering drawings proper to the art and science of welding is a must today.

It is quite apparent that our elders, the steel and gray-iron foundries, have recognized the talents welding has at its disposal, as evidenced by the tremendous advertising in the trade journals, to say nothing of technical improvements wrought in their products. Youth has caused the elders to sit up and take notice.

Tremendous emphasis has been placed on the materials and tools of welding; too little on the design aspect of the product.

A very prominent steel foundry man recently said most welding designers were borrowed from the foundries. This is a reality; we must train old and new men in welding design. Our society has taken tremendous strides in this direction, but we must increase the pace.

The American Weldment Mfr. Assn. has commended to help us by compiling data leading toward the standardizing of weldment design and procedure. This will help to give our market a level of quality and thereby help the industry in better understanding what to expect in weldments.

In the past few years, I have gradually formulated the following rules which I follow conscientiously in engineering, planning, and designing as a safeguard against hurried judgment which invariably leads to inferior products.

1. Loads imposed
   (*a*) Magnitude
   (*b*) Directions
2. Service
3. Application dimensions and surfaces
4. Stress calculations
   (*a*) Welds at low stress area
   (*b*) Calculation by stress analysis of weld size
5. Picturing
6. Consideration of price and appearance
7. Shop tools
8. Stress relieving
9. Shop consultation
10. Mechanical drawing
    (*a*) Over-all design assembly
    (*b*) Breakdown
    (*c*) Absence of "crutch" agencies (pattern shop, tooling, etc.)
11. Follow-through in shop.

Each of these eleven rules are of course subject to interpretation and finer subdivisions.

Let us examine each rule more thoroughly.

1. Loads Imposed. This rule as the heading indicates, directly involves the determination of the force brought to bear on the structure under consideration.

It has been the author's experience that in many instances, the customer does not know the magnitude of the loading. This must be known in order to lay the foundation of design. If a figure or figures cannot be obtained exactly, an estimate should be noted on drawings or folio work sheets to indicate the assumption upon which the designer has executed the work indicated. Particularly if the design under consideration is one wherein dynamic forces are imparted, the further step of direction and interrelation of forces should be ascertained.

2. Service. By service we mean the amount of "load usage" the structure is to withstand. Generally the words moderate, medium and maximum fill this category—each section subject to a numbered connotation applicable in the designer's reasoning and directly useful in Rule 4 under stress calculation.

With this the designer can begin to proportion the general section size. Using simple formulas such as $S = (P \times SF)/A$ he can arrive at a tentative estimate of the net area of section on which to impose the load.

3. Application Dimension. This will start to form a skeleton work of the structure and enable the designer

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to see the interrelation of contacting surfaces for load distribution. By this time, the designer is at the sketching stage wherein he has set to scale the construction-line-form surfaces and interrelated distances.

Now the designer can commence to see the beginning of his basic over-all weldment. Assumptions should be made of section sizes, width and length, roughly sketching this in place. This leads directly to an approximate stress calculation which will afford the designer a basis upon which to improve thereby more economically distributing material.

4. Stress Calculations. Having arrived at a trial section, a more complete stress analysis is made which will take into consideration the primary as well as secondary members, enabling the designer to determine the minimum possible net area of load distribution. At this same time, weld zones are indicated, and, from the center of gravity obtained in the direct stress analysis, the position of all welds with respect to the neutral axis are noted. Wherever possible, welds should be kept close to the neutral axis in order to minimize their size, thereby resulting in a saving of labor and weld rod.

If the structure is one wherein the welding required is relatively great, then a stress calculation on weld size is necessary to economize the weld zone. It is not sufficient to assume a weld of the size of the section being joined.

5. Picturing. Our next step is to stand off and consider wherein the theory has taken us. Does the structure have balance? Is the welding work readily accessible? Will there be an excessive amount of special tooling? Can the machine shop readily machine all application surfaces? Will jigs and fixtures be necessary?

6. Consideration of Price and Appearance. This step is so interrelated to the past thinking (Rule 5), it is only set apart to gain emphasis. Economy being the watchword, we must now test our structure for price. Without adding to this price unduly, we must also weigh the sales appeal. Too many weldments lack the appearance possible through systematic and proportional handling of parts, and it is often said that an efficient structure has good appearance. Many designers use the other extreme and attempt to copy other methods of fabrication and duplicate the appearance, for instance, of a cast product. In general, a weldment should not approach the appearance of a casting.

Without causing stress risers by sharp corners at critical areas along the extreme fiber, an efficient weldment can have a straight line form.

7. Shop tools. This rule is extremely important because the designer must not plan methods of forming, braking, shearing, etc., which will cause bottlenecks

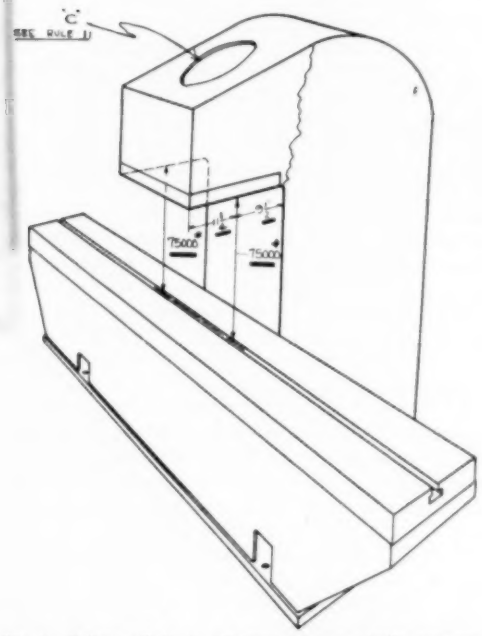

Fig. 1 Refer to Rule 5. Picture structure indicates general size and shape with pertinent and dimensional data. Rules 1, 3 and 6

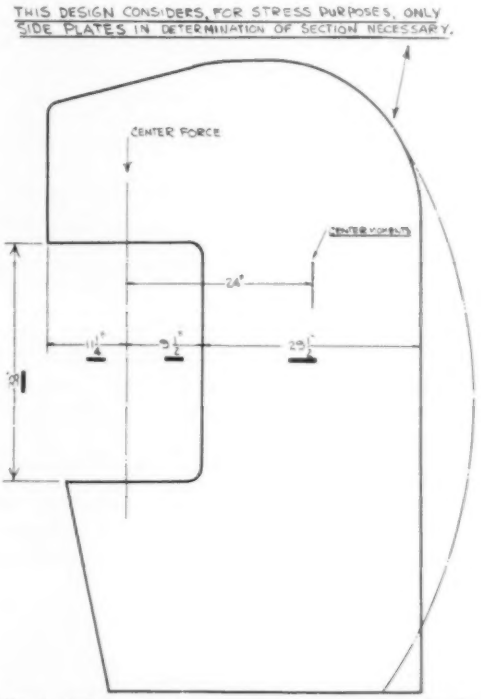

Fig. 2 Indicates for designer concise information for development of bending moment diagram. Dotted line indicates optimum shape. Refer to Rules 2 and 4

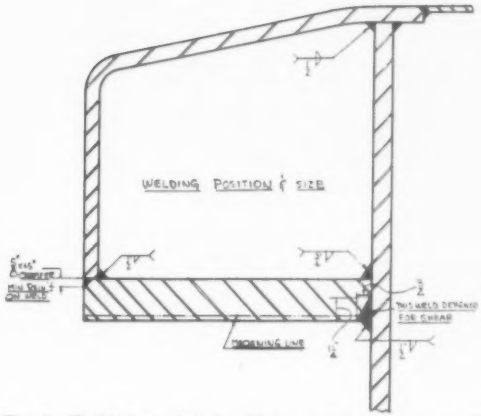

Fig. 3 Highlights critical weld zones for shop personnel indicating precisely weld sizes, flame-cutting data, machining and assembly. Refer to Rule 10

in the production department. The designer must know the tonnage available on presses, shears, etc., so that he may economize the design relative to the tools available.

8. Stress Relieving. Decisions on stress relieving are probably rivaled in popularity only by discussion on the weather conditions.

The designer should use common sense. If the structure is (*a*) one in which there is a relatively high degree of accuracy required after machining, then stress relieve; (*b*) if the structure is machined after welding and then firmly fastened by bolting to another machined structure and accuracy is not in thousands, do not stress relieve; (*c*) if the amount of welding relative to the weight of the structure is great, and/or if the welds are deep full-strength welds wherein cracks can be brought about in service, stress relieve.

9. Shop Consultation. Shop consultation in the engineering department follows. Advice from this vital department before final drawing will help the designer at least four ways: (*a*) gain confidence of the man who will see that his design is properly executed. (*b*) Iron out trouble points for the shop and thereby economize on man-hours. (*c*) Give the shop authority opportunity to anticipate needs and man-hour distribution. (*d*) Enable the designer to further understand the problems the shop must solve in poor design.

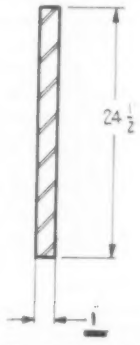

Fig. 4 Cross section through top center of plate shown in Fig. 2 and formula applying

10. Mechanical Drawing. Many early welding drawings were made on empty weld cartons. Scale drawings are important with more than the three standard views. Sections should be employed wherein multiple-size welds are shown in the same section length.

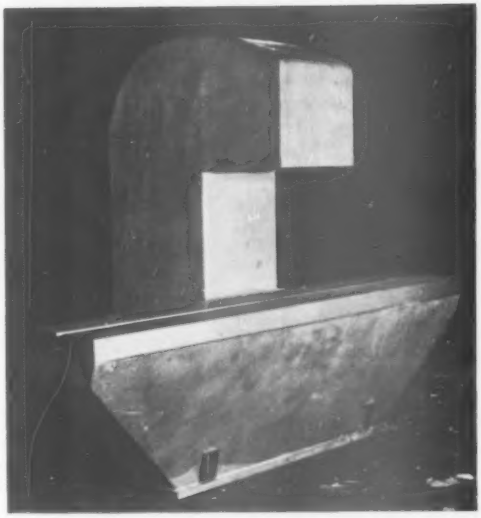

Fig. 5 Welded, snagged, stress relieved and sandblasted bare press, pictured in Fig. 1

The best drawing conveys the best thoughts. AMERICAN WELDING SOCIETY symbols should be employed to indicate size and position of welds. The designer should strive to explain the correct interpretation of weld symbols to the shop personnel. If possible, arrange for a class in weld symbols to assure correct understanding of the work.

Stress extreme accuracy in the design, since it goes directly to the shop. The pattern shop is not an intermediate step between engineering and the product. Those who have designed cast products know that many a mistake has been caught by the pattern department.

11. Follow-Through in the Shop. This factor is extremely important and manifests itself in the follow-

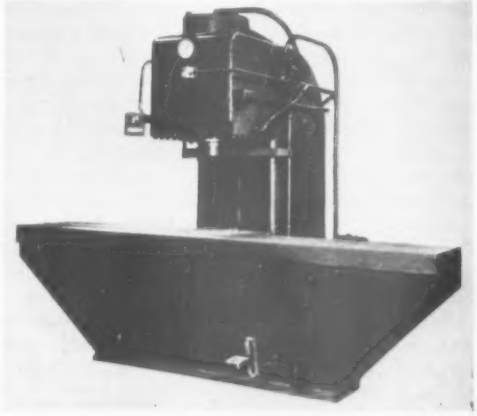

Fig. 6 Finished press as referred to previously in Figs. 1 to 5, inclusive

Solving for "*I*" Knowing "*D*":

$$D = \frac{WL^3}{3 \times E \times I}$$

$$0.010 = \frac{75{,}000 \times 24^3}{3 \times E \times I}$$

$$I = \frac{1160}{1}$$

where E = modulus of elasticity (30,000,000 steel)
I = moment of inertia
W = maximum load
L = effective lever arm
D = deflection in inches

Substitute Value of "*I*" Obtained Above and Solve for "*D*":

$$I = \frac{bd^3}{12}$$

$$1160 = \frac{1 \times d^3}{12}$$

$$d = 24.5 \text{ in.}^*$$

I = moment of inertia
b = plate thickness
d = plate width perpendicular to load

* Refer to Fig. 4.

Fig. 7 Simplified stress calculation to find section size. Side plates calculated to produce sufficient resisting force without aid of secondary members

ing ways: (*a*) Enabling the designer to assure himself his work has been executed as per drawing. (*b*) Gives the designer a first-hand account of troubles which may be corrected on future work. (*c*) Providing visual proof of the general appearance and practicability of his previous "paper reasoning." (*d*) Providing a final opportunity to correct, before shipment, any possible errors not seen by men working closely with the weldment.

To illustrate one application of the above rules in practice, the following problem is presented: Design a hydraulic "C" type press frame to withstand a loading of 75 tons with a maximum deflection of 0.020 in. at maximum loading. Bed to be 20 in. wide, 108 in. long, throat $20^3/_4$ x 33 in. etc. See Figs. 1 to 4, inclusive.

Powder Cutting and Scarfing of Stainless Steels

Powder cutting and scarfing properly applied with correct procedures and equipment provides a tool which places torch cutting and scarfing of stainless steels on almost the same basis as cutting and scarfing of mild steel

by C. W. Powell

THE increasing use of stainless steels has presented certain problems to the fabricators of stainless equipment in cutting sections for construction. Stainless is itself an expensive material and a difficult one to work as compared to carbon steels, each operation pyramiding the already high-initial material cost. Certain other fabrication methods, such as forging, drawing, oxyacetylene and electric arc welding, heat treating and others, have been modified and successfully applied to these high-chromium steels. Flame cutting, as applied to mild steels, was practically inoperable on stainless or at best time-consuming and expensive. In certain cases the use of a mild-steel rod or strip aided in fluxing the chrome oxide formed by the oxidation of the cutting flame, or the electric arc was used. In either case the operation was that of melting and left rough, jagged edges which required machining. With the advent of powder cutting we have been given a tool which has placed the torch cutting of stainless steel on almost an equal basis with torch cutting of mild steels.

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Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

TYPE OF WORK

In the Central Alloy District of Republic Steel Corp. we do no fabrication of stainless steel except in our maintenance shops and we will confine our remarks majorly to the stainless cutting and scarfing processes as used in Central Alloy District. Our problem, at present, is mainly one of salvage and the cutting of heavy sections. Our regular production cutting consists of trimming edges of slabs which have cracked badly in the rolling operation or in cutting slabs to order for rolling to sheets. All of our production is made to specific customer order and any overages of any order or any heats not meeting customers specifications is stocked in the form of slabs which are later applied to other smaller orders. Because of the numerous size slabs and various finished sheet sizes ordered a considerable amount of cutting is required. The method is used for salvaging portions of slabs which are partially defective, this before further expense is accumulated in rolling to sheets. These slabs vary from $2^1/_2$ to $4^1/_4$ in. in thickness. In regular cutting the $2^1/_2$-in. section is the lightest we cut. We have successfully cut all of the regular stainless grades although there are some which are more difficult than others, such as the high silicon, 25% chromium and 25% nickel types. Straight chromium types require special attention to prevent warping of the slab. If only one cut is to be made the slab should be pre-

heated to 400–500° F. If two parallel cuts can be made simultaneously preheating is not necessary.

Other applications of the method include the cutting of heavy scrap sections and ladle skulls for remelting. In some cases this applies to low-alloy steels as well as stainless. In one instance we found it economical to use powder to cut up scrap railway cars, an operation requiring welders as labor.

METHODS

There are two types of powder used, an iron of about 98% purity and sodium bicarbonate containing 1–1½% calcium phosphate to prevent caking both of which are injected into the flame. In the iron-powder method, two things occur which assist the cut, first, the oxidation of iron to iron oxide is an exothermic reaction and increases the flame temperature, and secondly, the iron oxide fluxes the chrome oxide allowing a fresh steel surface to be presented to the flame at all times. The sodium bicarbonate method is purely a fluxing operation, no additional temperature being generated.

The equipment used for the iron powder method consists of a standard 3-hose tubular cutting torch with standard tips, the size of which depend on the type of work done. The iron powder is introduced into the preheat flame by an annular ring placed at the end of the cutting tip and is perforated in such a manner as to direct the powder at an angle into the flame. The powder is conducted to the torch by means of compressed air through a separate rubber hose from the powder dispenser. There are two types of dispensers used, an aspiratory type and a vibratory feeder. In the aspiratory feeder the powder feeds down from the hopper into the aspirator section which is so constructed that the powder level is never above that of the needle type valve controlling the amount of flow. Compressed air at 4 to 8 psi. flows through a Venturi section in the valve itself producing sufficient suction to lift the powder through the valve and into the hose carrying on to the torch. The vibratory feeder consists of a hopper from which the powder is fed into the air stream by means of an electrical vibrator. Control of powder flow is had by increasing or decreasing the amount of resistance in the electrical circuit by means of a Variac. This latter type dispenser is much to be preferred because it is positive and easily adjusted and flow is not as readily affected by change in apparent density and particle size of the powder or slight amounts of moisture present. Uniformity of powder flow is absolutely essential to the maintenance and quality of the cut.

A modification of this method makes use of a mixture of nitrogen and hydrogen as the carrying medium for the iron powder. We are not familiar at this time with the effect of the nitrogen-hydrogen gas on the quality of the cut or the economics.

OPERATING DATA

Some typical operating data may be of interest here. In cutting 2¾-in. thick slabs of 18–8 type stainless we operate at an average of 12 to 14 in. per minute although we have cut as high as 17 in. per minute. For 4-in. slabs the speed will be 6 to 8 in. per minute, although 11 in. per minute has been reached. Powder usage is at the rate of 6 to 7 oz. per minute of torch time, cutting oxygen up to 13.0 cu. ft. per minute, preheat oxygen, .9 cu. ft. per minute and acetylene .8 cu. ft. per minute. The width of kerf is approximately ¼ in. These figures of course will vary with the operator, type of steel, size of cutting tip and gas pressures. The figures given would probably be average on a production basis. As stated before the thicknesses we cut vary from 2½ to 4¼ in. majorly in the range of 2¾ to 3½ in. We will probably average some 500,000 sq. in. cut per month. This figure is for production cutting only and does not include any scrap cutting which is on a 24-hr. basis or salvage of defective slabs. From these figures it may be said that for the fabricators of thinner sections stack cutting is feasible.

The process just described produces a good quality cut and it does not require any stationary preheat to start the cut. The process gives off brown fumes which are nontoxic and are not objectionable in well-ventilated rooms. One objectionable feature of this process is that there is a bead of fused powder and slag deposited on the top edge of the cut, sometimes extending over an inch back from the cut, which is very tenacious and difficult to remove. In many cases it is necessary that we grind off this bead before the slab can be rolled. We have found a slight carbon pickup on the cut edge. Twenty-four inch sections of 25% Ni–20% Cr have been cut by this method using additional preheat.

The equipment used for the sodium bicarbonate method, as in the case of the iron powder method, consists of a standard 3-hose tubular cutting torch using standard-sized tips. In this case the powder is introduced directly into the cutting-oxygen stream, at cutting pressures, in the powder dispenser. The powder dispenser is of the vibratory type and of the same general design as the one previously described. In this case the cutting oxygen is the powder-carrying medium and no extra hose or attachments are necessary. The bicarbonate powder being incombustible can be carried directly in the oxygen stream while the combustible iron powder cannot. The fact that the powder is carried in the oxygen stream means that a slightly larger cutting-oxygen orifice is required.

Some typical operating data for this method cutting regular 18–8 analysis show the powder usage to be 1.1 oz. per minute of torch time (this powder costing ⅛ that of iron powder), cutting oxygen up to 15.0 cu. ft. per minute, preheat oxygen 2.5 cu. ft. per minute and acetylene 2.2 cu. ft. per minute. Average cutting speeds for a 2¾-in. section would be 6 to 11 in. per minute although we have obtained speeds of 14 in. per minute, with corresponding lower speeds for heavier (4¼ in.) sections. We have seen data to the effect that in cutting 1-in. thicknesses of 18–8 the bicarbonate method is more rapid than the iron-powder method. The same limita-

tions of operator, type of steel, cutting tip and gas pressures also apply here.

QUALITY OF CUT

The process just described also produces a very good cut which is somewhat smoother than the iron-powder method and has a kerf of $^1/_8$ to $^3/_{16}$ in. and the top edge is lightly beveled. It does, however, require a 30- to 60-sec. stationary preheat at the point of initial start before the powder is turned on. This process more nearly approaches that of a true cutting operation whereas the iron-powder method leans toward the melting side. Brown fumes are also given off in this process which are nontoxic but are irritable to the mucous membranes. Here again properly ventilated rooms are required. This process does not produce the welded metal and slag bead at the top edge of the cut, in fact most of the slag produced pops off the work on cooling, no further grinding being necessary. We have been unsuccessful with this process in cutting stainless containing 2% silicon. We have cut 7-in. sections of 25% Cr–20% Ni analysis at $2^1/_2$ in. per minute. We are also able to cut the 18–8 type containing $2^1/_2$ to $3^1/_2$% molybdenum with comparative ease. As a matter of fact we have cut a 17-in. section of the molybdenum-bearing stainless using a great amount of preheat. These statements have only been made in an effort to show that neither method is a cut-and-dried process but that conditions in one plant may be such that results may be obtained which are not obtained in other plants.

Both methods of cutting produce changes within the steel that must be considered. The cutting temperature is such that, except in carbide stabilized analyses (Cb and Ti), there is an intergranular carbide precipitation extending in approximately 0.020–0.025 in. from the cut surface. With subsequent welding and/or annealing this presents no problem. Also we find that extending in from the cut surface from 0.100 to 0.125 in. the typical austenitic, irregular, many-sided crystal has been changed to a columnar structure. This may or may not be a problem to fabricators but in the production of sheet and strip this structure follows through to the finished product and must be scrapped.

The two cutting methods just described each have their place according to their limitations and the requirements placed upon them. The author does not wish to recommend either method but has placed the pertinent facts before you as we see them in the Central Alloy District. The greater part of our experience has been with the iron-powder method. We have not attempted to show you details of the subject equipment as you have probably already familiarized yourself with them from articles published in the many journals.

SCARFING

The final topic we wish to discuss is the powder scarfing of stainless steels. The process of scarfing is that of removing the surface defects of the steel by the oxyacetylene flame instead of grinding or chipping. The equipment for this process consists of an oversize, so to speak, hand-cutting torch having four hose connections for cutting oxygen, preheat oxygen, acetylene and iron powder. The compressed air-borne iron powder is injected into the cutting-oxygen stream within a specially constructed tip instead of into the preheat flame as in cutting. The handtrigger is so constructed that the cutting oxygen and the iron powder are started simultaneously. The powder dispenser used is of the aspirating type as described above but we can see no reason why the vibratory type of feeder cannot be used to advantage. In this operation the torch tip is held at an angle of approximately 15° to the work and upon pressing the trigger to start the oxygen and iron powder a spot of molten metal is deposited on the work and the fluxing action starts. The torch is then moved in the direction of the scarfing to be done, the fluxing action continuing. For shallow-surface defects this process may proceed at 50 to 60 in. per minute making parallel cuts, so to speak, about $1^1/_2$ in. wide. For deeper defects this speed may be materially reduced and gouging to a depth of 1 to 2 in. may be necessary. The powder usage for this process will vary from $^1/_2$ to 3 oz. per minute of torch time with oxygen and acetylene consumption approximately the same as for the cutting operation. So far as we know the scarfing of stainless steel can only be done by the iron-powder method.

We use this scarfing process only to salvage partially rolled ingots which have been rejected by the blooming mill because of poor surface. After scarfing, these "saddened" ingots as we know them, are returned to the blooming mill to continue their rolling to slabs. We do not scarf any slabs, as we understand is being done, because our experience has shown that with scarfed slabs the scarfing pattern appears in subsequent rolling to sheets.

In conclusion we wish to say that in our opinion the development of the powder cutting and scarfing processes has added materially to the economic working of stainless steels.

Welding in Engineering Education

The need for welding engineers is presented, the areas in which a welding engineer may be expected to operate are defined and the program for welding engineering education at Ohio State University is outlined

by R. S. Green

INTRODUCTION

THE purpose of the major part of this paper is to make a report to the AMERICAN WELDING SOCIETY on training in welding engineering being given at The Ohio State University. The curriculum was established in 1938 as a branch of the Department of Industrial Engineering and on Jan. 1, 1948, the Department of Welding Engineering was established as a separate degree-granting department of the engineering college. It is considered that an examination of the reasons for the establishment of this type of training are pertinent to the purpose of this paper; however, the five-year program under which the engineering college operates is not considered a major issue in this discussion.

A secondary topic which is touched upon briefly in conclusion is the problem of increasing the amount of welding education in the other engineering curricula. So many of our civil, mechanical, metallurgical and electrical engineers encounter welding problems in the course of their careers that it seems that additional training in the art and science of welding is indicated.

DOES INDUSTRY NEED WELDING ENGINEERS?

It is not necessary to point out to the membership of this group the wide application of welding in industry but it is well to think a moment concerning the dollar volume of business being done. The Welding Engineer Industry Estimates show over 205 millions of dollars spent in 1947 in the gas welding and cutting industry, 88 millions of dollars spent upon arc welding in 1948, and the resistance industry totals for the year 1948 were over 24 millions of dollars. The total expenditure for 1947 was over 306 millions of dollars for welding equipment and material alone. It is also evident that the use of 300 millions of dollars worth of welding equipment in this country indicates a much larger figure would be required to represent the value of welded products annually. On this basis a suspicion may be aroused concerning the desirability of training men for this industry.

Another piece of evidence of interest is to be found in looking at a membership directory of this SOCIETY for it is seen that of the titles listed "Welding Engineer" occurs quite frequently. It is apparent that in some degree at least industry is acknowledging a need, and is in fact leading educational institutions by some years, as is too often the case.

The reason that industry has often found it expedient to charge certain of its employees with responsibilities for the prosecution of welding work is found in the continuous transfer of the status of welding from an art to a science. The application of science in the welding field has been increasing and it is pleasing to note that the change has been assisted to a great extent by the efforts of this SOCIETY. The technical presentations of the SOCIETY have shown real evidence of the application of scientific training and thought to the problems of welding, and it is increasingly apparent that the welding field is no longer the province of the artisan and craftsman alone.

WHAT IS REQUIRED OF A WELDING ENGINEER?

If it may be assumed for the moment that the question of the necessity for welding engineers is decided in the affirmative then the next question of interest becomes what welding engineers do or what welding engineers are required to know. The very nature of welding problems often requires that they be attacked from more than one point of view. That is to say, a designer, mechanical or civil, may encounter considerable difficulty in dealing with a welding problem such as underbead cracking where metallurgical factors are large. Correspondingly a metallurgist may be at somewhat of a loss where design and shape factors play a predominant role such as in the case of hatch corners. From the welding equipment standpoint the electrical characteristics loom large and some background in the

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Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

field is predicated. Often a welding engineer works in close cooperation with production departments where an understanding of the principles of industrial engineering is required. To sum up we can say that a good welding engineer should be able to evaluate a welding problem whether the major element comes from design, material or production. A welding engineer should either be able to solve a welding problem from any one of these points of view or should obtain the services of specialists in these fields to achieve the desired result. This analysis indicates then that the training of a welding engineer should be as broad in technical phases as is possible.

Let us now consider what is meant by the term "Welding Engineering." Keeping in mind the preceding discussion of desirable attributes of a welding engineer the writer proposes the following definition of the practice of Welding Engineering:

"The practice of Welding Engineering involves knowledge of three basic areas in engineering: (1) the design of machines, structures and equipment as well as the design of suitable connections; (2) the materials of engineering with particular reference to metals, gases and refractories; and (3) the processes and procedures of the welding industry. The practice of Welding Engineering includes such professional service as consultation, investigation, evaluation, planning, design or responsible supervision of construction or manufacturing, when such professional service requires the application of engineering principles and data."

With the foregoing as a reference point the writer suggests that: "A Welding Engineer is one who, by reason of his special knowledge of the mathematical and physical sciences and the principles and methods of engineering analysis acquired by professional education and practical experience, is qualified to practice Welding Engineering as defined in the preceding paragraph."

The thinking underlying these definitions has been the guiding factor in the development of the Department of Welding Engineering. Our intent is to train men who when they have had sufficient practical experience after graduation will essentially fulfill the preceding statements or definitions. Our work should be judged on two counts, one whether or not we have been properly guided in setting up our objectives, and, two, upon our success or failure in meeting those objectives.

TRAINING WELDING ENGINEERS

A certain philosophy has governed the design of a curriculum for the purpose of training welding engineers. Major tenets are: (1) That training shall be firmly based in mathematics and the physical sciences, (2) that the technical training or the training in the application of science shall be as broad as possible, (3) that it is the job of the university to give scientific training and that it is the job of industry to provide the experience required to complete the education of an engineer and (4) the purpose of the technical or applied science courses is to teach basic scientific principles and to show their relationship to engineering, not merely to provide a collection of unrelated data and skills.

We feel that the very nature of the welding field is such as to preclude the possibility of training for a narrow area of specialization. It is concluded that a high degree of specialization would be a distinct disservice to industry and students alike. It is perhaps an oversimplification but indicative nevertheless to define our purpose to be that of training men to make things out of metal. This approach is not traditional for through the years engineering colleges have often moved to compartment and divide up the engineering field. This tendency may be entirely justified in some cases; however, it leaves us with graduates in civil engineering who feel incompetent to handle a problem relating to a machine with moving parts, and mechanical engineering graduates who are overcome by the thought of dealing with a roof truss or a rigid frame. The same basic principles of mechanics underlie both fields but often, with specialized types of training, students do not recognize the fact. With both groups of engineering students, all too often steel is a black hard substance that has an ultimate strength, yield point and some percentage elongation and little more is known or cared to be known. Many engineers with some years of industrial experience will agree that in practice an engineer often has to cut across arbitrary boundaries to solve a problem or to design a plant or product, and moreover it is quite likely that in the course of a long career that an engineer may expect to hold many jobs whose requirements differ from his original training. Thus in our thinking a curriculum in welding engineering must be based firmly on the idea of broad fundamental training.

THE WELDING ENGINEERING CURRICULUM

The writer has shown the area in which it is expected that welding engineers will operate and what type of person we wish to have as a finished product. It is

Table 1—Curriculum in Welding Engineering

	Hr.
First Year (Common to all Engineering Departments)	
Mathematics	15
Chemistry	12
Engineering Drawing	12
English	9
Survey of Engineering	2
Military Science	6
Physical Education	3
	59
Second Year	
Mathematics (Calculus)	15
Physics	15
Shop Laboratory Courses	
Machine Shop	3
Foundry Practice	3
Welding and Heat Treating	3
Economics	6
Psychology	3
Military Science	6
	54

Third Year	
Mathematics (Differential Equations, Fourier Series, Bessel Functions, Vector Analysis, Operational Calculus)	9
Mechanics	16
Metallurgy	12
Engineering Drawing	3
Kinematics	5
Nontechnical Sequence	9
	54
Summer Quarter—Industrial Experience	6
Fourth Year	
Welding Engineering (Processes & Equipment, Theory, Applications)	9
Electrical Engineering (A.-C., D.-C. Circuits, Electronics)	12
Mechanical Engineering (Machine Design, Thermodynamics)	15
Civil Engineering (Stresses, Rigid Frames)	8
Advanced Strength of Materials	3
Nontechnical Sequence	9
Inspection Trip (1 wk.)	2
	58
Summer Quarter—Industrial Experience	6
Fifth Year	
Welding Engineering (Structural & Machine Design, Resistance Welding)	15
Industrial Engineering (Principles of Industrial Engineering, Management, Safety)	10
Technical Elective	15
Nontechnical Elective	15
Survey of Engineering	1
Inspection Trip (1 wk.)	2
	58

now necessary to translate these ideas into an effective educational program. Certain academic requirements must be met in planning the program. For instance, the duration of training is five years as adopted by our engineering college. There are other technical requirements with respect to total hours and the minimum amounts of time devoted to mathematics, physical sciences and nontechnical courses. The curriculum in welding engineering has been developed within these academic requirements with the intent of producing men with the broad technical training required in the welding field.

Table I outlines the curriculum in welding engineering and specifies the number of academic hours devoted to each course. The first year is common to all engineering curricula at Ohio State and is similar to freshman programs in many engineering colleges. The second year is also similar to that of some of the other branches of engineering. The third year of the program begins to show the difference between the several departments and their method of training. The curriculum in welding engineering requires a third year of advanced engineering mathematics beyond the calculus, more mechanics than in some curricula and a full year in the Department of Metallurgy. Kinematics and engineering drawing lay the foundation for machine design courses to follow. At the conclusion of the third year a summer of industrial experience is required and our students are encouraged to obtain work as welding operators whenever possible.

The program for the fourth year includes a year of electrical engineering, two quarters of machine design, thermodynamics, two quarters of structural design and one quarter of advanced strength of materials, and in this year the advanced sequence in welding engineering begins. The courses in welding engineering are not started until the fourth year because it is desired to have a proper foundation in metallurgy and mechanics to build on. Summer quarter industrial experience is a requirement at the end of the fourth year.

The fifth year is composed of a year of welding engineering courses, a year of industrial engineering courses and a year of both technical and nontechnical electives.

Table 2 is a summary of the requirements of the welding engineering curriculum and expresses in terms of academic hours and on a percentage basis the relative weight assigned to each portion of the curriculum. It is perhaps interesting to note that mathematics is given more time than any other required subject.

The concept of providing a broad technical education based upon fundamental engineering principles is one which has the approval of most engineering educators; however, it is the application of this concept which differentiates between curricula. Figure 1 gives a profile of the percentages of time devoted to ten subjects by the Departments of Civil, Mechanical, Electrical, Industrial, Metallurgical and Welding Engineering of The Ohio State University. The thought has been expressed that training in welding engineering must certainly be very narrow and highly specialized. The writer has indicated that the objectives of the Department of Welding Engineering are quite the reverse, and Fig. 1 and Table 3 are included to show how in practice the question of specialization is handled. It may be seen that only the Electrical Engineering Dept. requires as much mathematics as the Welding Engineering Dept. and also that Electrical Engineering is the only department with more physics in its curriculum. The welding engineering curriculum requires more mechanics than any other department in the engineering college, and it is seen that welding engineering students take more metallurgy than any students but those specializing in metallurgy. The same statement holds for work in mechanical engineering, civil

Table 2—Summary of Requirements for the Degree Bachelor of Welding Engineering

	Hr.	*Per Cent of Total*
Mathematics	39	13.91
Physics	15	5.36
Chemistry	12	4.29
English	9	3.21
Engineering Drawing	15	5.36
Survey of Engineering	3	1.07
Military Science	12	4.29
Physical Education	4	1.43
Economics	6	2.14
Psychology	3	1.07
Mechanics	19	6.79
Metallurgy	12	4.29
Mechanical Engineering	20	7.14
Electrical Engineering	12	4.29
Civil Engineering	8	2.86
Industrial Engineering	16	5.71
Welding Engineering	27	9.64
Technical Elective	15	5.36
Nontechnical Elective	33	11.80
Total	280	100.01
Inspection Trips	4	
Industrial Experience	12	

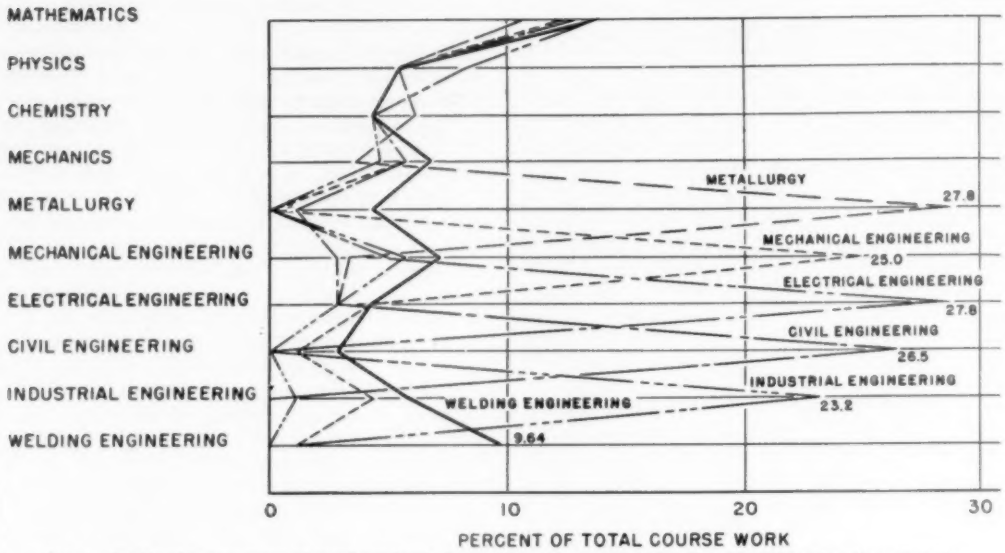


Fig. 1 Profile of percentages of total academic hours devoted to ten subjects by six engineering departments

engineering and industrial engineering. To proceed with the investigation of the relative degree of specialization as indicated by the proportion of work done in the major departments, we find that percentages of time vary between 23.2 and 27.8% for the five departments considered and that the time for specialization in Welding Engineering is in the order of 10%. There is therefore some evidence to indicate that training in welding engineering has the broadest technical base of any of the curricula considered. It should be pointed out that in each curriculum an additional fifteen hours (5.35% of the total hours) are shown as technical electives and in practice are often taken in the major department.

Table 3—Percentages of Total Academic Hours Devoted to Ten Selected Subjects by Six Departments of Instruction at The Ohio State University

Mathematics		Physics	
Welding Engineering	13.91	Electrical Engineering	8.20
Electrical Engineering	13.91	Welding Engineering	5.36
Civil Engineering	12.80	Civil Engineering	5.36
Mechanical Engineering	12.50	Mechanical Engineering	5.36
Industrial Engineering	12.50	Industrial Engineering	5.36
Metallurgical Engineering	10.70	Metallurgical Engineering	5.36
Chemistry		Mechanics	
Metallurgical Engineering	6.08	Welding Engineering	6.79
Welding Engineering	4.29	Civil Engineering	5.71
Electrical Engineering	4.29	Mechanical Engineering	5.71
Civil Engineering	4.29	Electrical Engineering	4.64
Mechanical Engineering	4.29	Industrial Engineering	4.64
Industrial Engineering	4.29	Metallurgical Engineering	3.57
Metallurgy		Mechanical Engineering	
Metallurgical Engineering	27.8	Mechanical Engineering	25.0
Welding Engineering	4.29	Welding Engineering	7.14
Civil Engineering	1.07	Industrial Engineering	5.71
Electrical Engineering	0	Electrical Engineering	5.0
Industrial Engineering	0	Metallurgical Engineering	3.21
Mechanical Engineering	0	Civil Engineering	2.86
Electrical Engineering		Civil Engineering	
Electrical Engineering	27.8	Civil Engineering	26.5
Welding Engineering	4.29	Welding Engineering	2.86
Mechanical Engineering	4.29	Mechanical Engineering	1.07
Civil Engineering	2.86	Electrical Engineering	0
Industrial Engineering	2.86	Industrial Engineering	0
Metallurgical Engineering	2.86	Metallurgical Engineering	0
Industrial Engineering		Welding Engineering	
Industrial Engineering	23.2	Welding Engineering	9.64
Welding Engineering	5.71	Mechanical Engineering	1.07
Mechanical Engineering	4.29	Industrial Engineering	1.07
Electrical Engineering	1.07	Civil Engineering	0
Civil Engineering	0	Electrical Engineering	0
Metallurgical Engineering	0	Metallurgical Engineering	0

THE WELDING ENGINEERING COURSES

The first welding engineering course is one designed for sophomore industrial, mechanical and welding engineering students and is called "Welding and Heat Treating." This basic course covers the heat treatment of carbon steels, the welding processes and applications of the welding processes. The laboratory time for this course is divided between heat treatment, oxyacetylene welding and cutting, and electric arc welding. The objective of the course is to provide students with the engineering background of the welding processes, and the mechanical skill developed is of secondary concern.

There are six advanced courses which form the core of work offered in the department. These six courses are required of all welding engineering majors, though up to fifteen hours' additional work in the department are commonly elected by these students. The first course of the six is "Welding Processes and Equipment," a course designed to cover the principles related to each of the welding processes and design and detail information concerning the equipment required. The second course "Theory of Welding" is concerned very largely with the application of the principles of physics and metallurgy to the welding field. Shrinkage and residual stresses are studied as well as the multiaxial stress states. The third course of the series "Applications of Welding Engineering" is concerned with the layout of connections and details, the analysis of the stiffened plate condition and a study of codes and specifications pertinent to the welding field. These first three courses are given in the fourth year of the program at which time students can be expected to be reasonably conversant with the mathematics, mechanics and metallurgy associated with the field.

The remainder of the six-course series is offered in the fifth year of the program. The fourth in the series is titled "Welding Design" and is concerned primarily with structural design for welding. A knowledge of rigid frame analysis is presupposed and both simple and indeterminate structures are designed for welded construction. The fifth course, "Welding Design," is design for welding in the mechanical field. Machine parts as well as some piping and pressure vessel work are considered. Particular attention is paid to the choice of either weldments or castings in order to economically produce a product. The sixth in the series is "Applications of Resistance Welding." The fundamental electrical characteristics of resistance welders as well as the types of resistance welders and processes are taken up. Maintenance of equipment, jigs and fixtures, controls and timing devices and electrodes are considered. The principles of design for resistance-welded products are studied.

In most cases students will elect to supplement the courses discussed above with additional welding engineering courses as provided in the fifteen hours of technical electives shown in the curriculum, Table 1. Often much of this time is devoted to research problems in the department laboratory.

PHYSICAL PLANT AND CAPACITY

Currently, the laboratories of the Department of Welding Engineering occupy something more than 10,000 sq. ft. of space and legislative appropriation has been made for the addition of about 5000 sq. ft. of laboratory space.

The laboratory equipment includes 18 heat treating furnaces of various types, 28 stations for oxyacetylene welding and cutting and 28 stations for electric arc welding. Specialized types of welding equipment are available such as resistance welders, inert-gas-shielded welding equipment, atomic hydrogen, metal spray, etc. Shears, grinding wheels, power hack saws, drill presses and other metal working tools are available in the department shop. X-ray equipment on hand but not yet installed includes 400-, 220- and 140-kv. units.

The laboratory after present construction is completed is designed to accommodate from 125 to 150 students majoring in welding engineering and in addition to handle service courses for other departments of the engineering college. Classroom space outside the department area is required to handle current loads. The maximum output of welding engineering graduates is estimated at 25 per year.

GRADUATES IN WELDING ENGINEERING

The demand for graduates in welding engineering has always considerably exceeded the supply. The shortage of experienced welding engineers has placed graduates of the department in an enviable position with respect to employment and compensation.

Typical titles of welding engineering graduates in industry are as follows: Engineer, Director of Research and Development, Welding Engineer, Manufacturing Engineer, Production Manager, Metallurgical Engineer and Process Engineer.

Companies employing graduates of the department are quite varied in their fields. Representative companies are: Standard Oil Co., R. C. Mahon Co., Marion Power Shovel Co., Westinghouse Electric Corp., Battelle Memorial Institute, Harnischfeger Corp., Johnson Mfg. Co., Clark Equipment Co., Fisher Body Co., Belmont Iron Works, Combustion Engineering Co., International Harvester Co., Surface Combustion Co., Graver Tank and Mfg. Co., Riehle Testing Machine Co., Creole Petroleum Corp., The Buda Co., Youngstown Sheet and Tube Co., Lustron Corp., Park Iron and Welding Co., Lakeside Bridge and Steel Co., and American Mine Door Co.

The first class in welding engineering graduated in 1941 and they have taken increasingly important positions in industry. J. R. Stitt, of Detroit, recently pointed out that currently two of the chairmen and one secretary of A.W.S. Sections are graduates in Welding Engineering, and that many other graduates have been active in section affairs. This progress seems creditable particularly since it has been only eight years since the first class was graduated.

Prospects for future employment of graduates in Welding Engineering seem very satisfactory. The change from a sellers market to a highly competitive market has slowed the demand for some types of engineering graduates; however, this competitive condition in industry seems to have increased the demand for welding engineers. Many industrial organizations are engaging in welding operations for the first time in an effort to reduce production costs. Very often these organizations which are turning to welding, or increasing their use of welding, need trained men. Obviously, such a company would prefer experienced welding engineers but often they find such men not readily available and the recent graduates are desired to fill these positions. Often our graduates have been placed in positions somewhat senior to their years and experience, but reports on their performance have been rather satisfying to the university.

One other basic reason for an optimistic view with respect to future employment lies in the broad technical training given these men. Graduates in welding engineering are fitted to engage in other engineering work not directly related to the welding field. Past experience indicates that our graduates can and do reach into many other phases of the metal industries than that for which they were originally trained. It is felt that these men will be better prepared to weather any periods of depression in the business cycle than those trained along more specialized lines.

THE INTRODUCTION OF WELDING INTO OTHER CURRICULA

It is evident to this group that many other classes of engineers need some background in the application of welding to their particular branch of engineering. Notable among them are mechanical engineers for the wide application of welded construction in machinery, pressure vessels and piping is well known. Civil engineers doing structural work are often faced with welding problems or designs which might be more simply and economically executed as welded structures. Metallurgists are very frequently called upon to solve welding problems, and the electrical engineers play a major part in the design of equipment and controls for welding. A very large percentage of these groups previously mentioned come into direct contact with one or more phases of the welding field, and yet their welding training is often very sketchy. It is common in universities with laboratory facilities to require students in some of their engineering departments to take one laboratory course in welding. This single laboratory course may be on a skill or craft basis, with little emphasis upon fundamentals and applications. After having this single course it is seldom that welding plays any important part in the remainder of the program. This indifference to the part of welding in industry is not consistent with the requirements graduates must eventually meet.

A very natural place to continue welding training comes in classes of engineering drawing. Current textbooks in engineering drawing contain welding symbols and brief chapters on their application to engineering drawing. This material is often taken up late in point of time in courses and sometimes is not reached at all. It would seem that welding symbols should find their place early in the sequence on fasteners, and that they should be used throughout the course where possible. Engineering drawing problems frequently make use of castings but seldom do they make use of weldments. The desirable treatment would seem to study welding symbols early in the program and continue to use weldments in problems where they are suitable throughout the course, rather than assigning one or two days toward the end of the quarter for welding topics.

Machine design courses seldom include design for welding and when it is done it forms a very minor part of the course work. There is the well-known reluctance of some machine designers to consider the application of welding to machine parts; however, industry has certainly pointed the way in this field. The choice of the proper method of fabrication of machine parts is certainly a function of the designer and it would seem sensible for machine design courses to recognize and exploit the advantages of welded construction. The other large area in mechanical engineering is that of pressure vessels and piping which is particularly suited for welding applications.

The point which is being striven for here is that to increase the amount of training in the welding field it is particularly advantageous to have welding taught as a part of existing courses in civil, mechanical, electrical, industrial and metallurgical engineering. Additional courses in the welding field are certainly advantageous; however, these courses cannot be of maximum benefit until the applications of welding are taught in the areas of specialization. As interest can be aroused and as information can be disseminated then we may expect welding to take its place in engineering education.

THE ROLE OF THE A.W.S. IN WELDING ENGINEERING EDUCATION

The education of welding engineers should be a major concern of this Society, as well as the training of engineers in other branches to apply welding in their own fields. Mere passive acceptance of such programs as are in effect does not seem enough. With respect to training welding engineers it would seem that this Society should either actively support such efforts as are being made or actively discourage such efforts if the training offered does not meet reasonable standards.

Among the things this Society might do are: (1) agree on an acceptable definition for the practice of Welding Engineering and to define the term "Welding Engineer," (2) come to a decision as to whether this

group recommends training of students in welding engineering, (3) make recommendations concerning professional education in welding engineering now offered or in prospect, (4) actively assist universities engaged in training welding engineers and those planning such programs and (5) take positive leadership in establishing and recommending standards for the education of welding engineers and cooperate with the Engineers Council for Professional Development in inspecting welding engineering training programs.

CONCLUSION

The principal aims of this paper have been to present ideas with respect to the need for welding engineers, to define the areas in which a welding engineer may be expected to operate and to delineate the philosophy which has guided the development of the program in welding engineering at The Ohio State University. We are willing to be judged upon our program as stated herein. Constructive criticism from engineers and educators alike is desired and invited. The work of the Department of Welding Engineering is more closely related to the work of this SOCIETY than any other technical group, and for that reason we hope the AMERICAN WELDING SOCIETY will see fit to make the education of future welding engineers a matter of its own deep concern.

The International Institute of Welding

by G. Parsloe

THE movement for the formation of an international welding organization goes back to a meeting of the Dutch Welding Society at Utrecht in 1947, when representatives of several European welding societies happened to be present. It was agreed that an international society was needed and that the bodies represented should join together in exploring the means of bringing it into being. A preparatory Committee was set up at London in the following September, upon which the representatives of seven countries were invited to serve, and a draft constitution was produced by this Committee in meetings held at Paris and Basel.

FOUNDATION

The constitution so drafted was laid before the inaugural meeting in June 1948, when twenty-seven welding societies of twelve countries agreed to join the International Institute. Other societies have since been elected and the supporting countries now are: Austria, Belgium, Denmark, Finland, France, Great Britain, Italy, the Netherlands, New Zealand, Norway, South Africa, Spain, Sweden, Switzerland and the United States. The first President, elected with all the honorary officers at the inaugural meeting, is M. P. Goldschmidt, President of the Belgian Welding Institute. The three Vice-Presidents are Dr. H. E. Jaeger, Professor of Naval Projects at the Technical University of Delft, Dr. A. B. Kinzel (U.S.A.), and Prof. A Portevin, Member of the Academy of Sciences of the Institut de France. The Treasurer is W. Edström (Sweden) and the Secretary-General is G. Parsloe, the Secretary of the (British) Institute of Welding. These officers, all of whom hold office for a fixed term of three years, constitute an executive committee for the Governing Council, commonly called the Bureau.

G. **Parsloe** is Secretary, International Institute of Welding, London, England.

OBJECTS

The object of the Institute is defined as: "To promote the development of welding by all processes." To this end the Institute seeks to encourage the development of welding as regards both welding equipment and its application, to promote the exchange of scientific and technical information relating to welding research and education, to assist in the formation of international standards for welding, in collaboration with the International Standards Organization and to organize periodical congresses. The Institute may not engage in commercial or trade activities and expressly excludes from its concern prices, wage rates, markets and agencies.

In the preparatory period, within the first year or so of its existence, administrative and formal matters have necessarily claimed much of the attention of its founders. The constitution had to be drawn up and set on paper, and experience had to be gained in the business of organizing international meetings. Now that these preliminaries are over, the Institute is coming to grips with its real interests and is turning to the technical tasks by its success in which it will stand or fall.

The meeting held at Delft in Holland last May was really the first of the annual meetings of the Institute. A meeting held in the previous June at Brussels, Belgium, was the foundation meeting and the pattern for the future was drafted at Delft, where, for the first time,

The President addresses the Governing Council in the 17th century Aula of the University of Delft in May 1949. Left to right at the table are: Prof. A. Portevin, Prof. H. E. Jaeger, M. P. Goldschmidt, G. Parsloe and W. Edström

the various technical Commissions of the Institute gathered to consider their programs. The next meeting will be held June 5–10, 1950, at Paris.

THE COMMISSIONS

It is upon the Commissions that the technical work falls. There are at present thirteen of these and the decision to set up twelve of them was taken less than eighteen months ago at the Brussels meeting. Every participating country is entitled to representation on each of the Commissions and it naturally took some time merely to bring them into being, in view of the distances separating the member societies and the difficulty of maintaining contacts among countries so recently ravaged by war and preoccupied by reconstruction. It was, therefore, something of a triumph that each of the Commissions was able to hold a meeting at Delft and to discuss its own program of work. These programs had been drawn up, in most cases, by the Chairman and circulated to the Commission during the previous month or two, and the object of the discussions at Delft was primarily to secure agreement on the programs and on the order in which the tasks listed in them should be tackled.

The Commissions are of several different types. First, there are three process Commissions concerned, respectively, with Gas Welding, Arc Welding and Resistance Welding. Next, there are the Commissions on Documentation, on Terminology, on Standards and on Hygiene and Safety, all of which are, in the main, concerned with the collection and correlation of existing information.

Lastly, there are the Commissions which deal with particular aspects of research, namely those on Testing, Measurement and Control, on Weldability, on Residual Stresses, on Stress Relieving, on Brittle Fractures and on Fatigue Testing.

THE PROCESS COMMISSIONS

The Gas Welding and Allied Processes Commission, of which Mr. Keel, Director of the Swiss Acetylene Society, is Chairman, has agreed to concentrate, for the present, on three problems, each of which has been confided to a rapporteur who will collect and digest information from the cooperating countries. The problems are powder cutting (rapporteur, R. E. Doré—Great Britain), the improvement of the quality of various metals for steel welding (rapporteur, J. Aversten—Sweden) and research on the modification of cutters with a view to making the process more economical (rapporteur, M. H. Renaudie—France).

The Electric Arc Welding Commission, presided over by Prof. H. E. Jaeger (Netherlands) has set up a number of Subcommissions to investigate the classification of electrodes, methods of testing and measurement, the qualification of welders, the welding of nonferrous metals with inert gases and the equipment for connecting arc welding plant with the main. In addition, each member of the Commission has been asked to collect information in his own country on the regulations for the construction and supervision of welded boilers and to consult with the national experts on the welding of bridges and the welding of ships, with a view to a possible program of investigation into the problems arising in these two important applications.

The Chairmanship of the Resistance Welding Commission has been accepted by Wilson Scott of the Westinghouse Corp., in whose unavoidable absence the Chair

was taken by H. Van Nooyen (Netherlands). The Commission decided to proceed by collecting existing documents on a number of subjects and transmitting them to the Secretary of the Commission, who would prepare reports based upon them. The subjects are the classification of resistance welding methods, the definition of resistance welding terms, the classification of resistance welding machines and the working out of a schedule for weldability. The British and French delegates agreed to circulate documents on the education of electrical engineers in their respective countries.

SOMETHING ACHIEVED

While other Commissions, as already explained, were planning their future work, the Commission on Documentation was examining its first achievement, the first issue of the *Bibliographical Bulletin for Weldir g and Allied Processes*, compiled and published by the French Institut de Soudure in English and French, from abstracts in part furnished by the cooperating countries and in part obtained from the literature of those outside the Institute. Four issues of this invaluable quarterly publication have now appeared, and the full extent of the service which the French welding experts are rendering to the International Institute and to their colleagues in all countries can now be appreciated. The abstracts, which are printed in both languages on facing pages, are arranged in an elaborate subject classification and form a more comprehensive guide to the literature of welding than any available hitherto. The Bureau have passed a special resolution of thanks to the French Institut for this work, which certainly deserves the active support of all welding societies throughout the world. The Commission also expressed its appreciation, approved proposals to publish a yearly index of authors, to examine the possibility of publishing abstracts of patents and to consider whether it would be practicable to correlate the present classification system with the universal decimal classification.

STANDARDIZATION

As the objects of the Institute make clear, it has always been the intention to work in collaboration with the International Standards Organization, and the Institute's Commission on Standards (Chairman, M. Leroy—France, who was also Chairman of the 1949 meeting of the Welding Committee of I.S.O.) is essentially a liaison body, transmitting to other Commissions problems referred to the Institute by I.S.O. and collecting from them material of importance to I.S.O. It is, therefore, particularly encouraging that the International Standards Organization has already passed to the Institute for study matters connected with weldability and in particular with its mechanical aspects, and has instructed its special Commission on Filler Metals and Electrodes to work in consultation with the International Institute.

The Commission on Terminology (Chairman, M. Van Horenbeeck—Belgium) is working toward the production of a multilanguage welding dictionary. At the Delft meeting it was agreed that each member country should draw up complete lists of specific welding terms for inclusion in the dictionary, the sections of which would then be divided among the countries for editing, after which each country would prepare definitions for the terms in its own language. The Dutch and Belgian Welding Societies were already engaged in the production of a four-language dictionary before the Institute was founded, and have put the work already done at the disposal of the Commission, which is thus able to make quicker progress than might have been expected.

The Chairman of the Hygiene and Safety Commission is Prof. S. Forssman of the Swedish State Institute for Public Health. The Commission has decided to concentrate for the time being on the study of risks from gases and fumes of the gas welding flame, especially nitrous oxides, risks from gases and fumes from the electric arc and electrodes and protection against ultraviolet rays and infrared rays. These main topics have been subdivided into a number of specific problems, on which members of the Commission have undertaken to gather and collate information in their own countries.

THE RESEARCH COMMISSIONS

The President of the Institute, M. P. Goldschmidt (Belgium) is the Chairman of the Commission on Testing, Measurement and the Control of Welds, which at Delft examined nondestructive methods of control and prepared a scheme for the classification and designation of the faults revealed by radiography. L. van Ouwerkerk (Netherlands) agreed to make further investigations on this subject and to communicate results to the Commission for discussion at the next meeting. Arrangements were also made to gather information on supersonic methods of control and destructive and semi-destructive testing methods.

The Weldability Commission (Chairman, M. Geerlings—Netherland) has set up Subcommittees to deal with definition of weldability and weldability tests, the problem of hard zone cracking and the comparison of steels suitable for welding.

The Commission on Residual Stresses (Chairman, Dr. R. Weck of the British Welding Research Association) agreed to investigate first a method of measuring, which could be recommended for international use in order to define residual stresses and shrinkage. Members undertook to supply information on the instruments used and the methods of working in their own countries.

The Commission on Stress Relieving (Chairman, Prof. W. Soete, Scientific Adviser to the Belgian Institute of Welding) is collecting information on a number of subjects in the following order of priority: (*a*) local

heat treatment at 600° C.; (*b*) low-temperature stress-relieving procedure (Linde procedure); (*c*) low-temperature heat treatment, c. 250° C.; (*d*) peening; (*e*) stress relieving by static deformation.

The Commission on Brittle Fractures has not yet obtained a permanent Chairman, but the AMERICAN WELDING SOCIETY and the Welding Research Council have been invited to appoint one. The meetings at Delft, therefore, took place under the Chairmanship of M. J. A. Haringx (Netherlands). It was decided to begin study of the following problems: (*a*) the correlation between more or less brittle fractures occurring in welded structures and the results of the various tests carried out on base metal and on welded specimens, (*b*) the phenomenon of fracturing from a more theoretical point of view, in order to gain a better insight into the relations between testing methods and the fractures occurring in actual welding. Subcommissions were set up to collect, study and interpret the information on fractures and tests and for the theoretical investigation of more or less brittle fractures.

The Chairman of the Commission on Fatigue Testing is Prof. M. Ros (Switzerland). This Commission was only established at the Delft meeting and its program has not yet been drafted.

PUBLICATION OF RESULTS

It will be seen from the foregoing survey that much of the work of the Commissions, at least in the early stages, lies in the gathering, correlation and interpretation of existing information. It is, however, likely that this will suggest lines of investigation of an original character. The Institute has no means of conducting such researches itself, so that the representatives of the various member countries will presumably undertake such investigations, when there are available to them appropriately equipped research organizations in their own countries. Since the work will not be financed by the International Institute, it is obvious that it will only be undertaken by bodies which expect the results to justify their outlay, and it is entirely reasonable that those who pay for an investigation should have freedom to publish the results as they see fit. The rule which the Institute has therefore adopted is that members of a Commission undertaking work for the Institute are free to publish the information on their own work, but that announcements to be made to the technical press regarding the work of the Commission as a whole are reserved to the Institute. Since the Institute has as yet no publication fund, papers presented at its meetings appear in the technical press of the member countries, and especially in the journals of the member societies.

FINANCES

Welding societies are not, as a rule, wealthy bodies and no International Institute could have been brought into being, if the subscriptions of the member societies had not been kept within modest limits. The total revenue of the Institute at present is less than $2000 a year.

It will be obvious that such an organization cannot establish an expensively paid secretariat and that the bulk of its work has to be done by volunteers. This in turn limits both the amount that can be done and the speed with which it can be done, because those who give their help in various ways to the Institute and its Commissions are, for the most part, busy men, whose duties to their employers come before their obligations to the International Institute. It would be absurd to expect important additions to our knowledge to flow rapidly from such an organization, but those who have already taken part in its work show a cautious satisfaction with the distance covered so far. How far and how fast the Institute may go depends essentially on the willingness of welding enthusiasts to play their part in building it up.

It is always those who are able to take part in the meetings of such a body as the Institute who are the most enthusiastic, for the good reason that they alone can form any definite picture of what the organization means. To listen to and perhaps take part in a technical discussion among experts is a stimulating experience and the meetings at Delft, which attracted about 150 people, certainly seemed worth while to those who had been there.

As yet the Institute has little but promise to attract the support it needs, and it is men of faith and vision who will recognize in it the small and unpretentious beginnings of what may become a powerful influence in the development of the welding processes. But even so early there is the *Bibilographical Bulletin* as the tangible fruit of cooperative effort, and there are plenty of ideas, the outcome of that "fertilizing contact of mind with mind," which it is the primary task of any international body to promote.

The New Metals—Molybdenum, Titanium and Zirconium

THE commercially available materials are not always adequate for the severe high temperature or corrosive conditions which are encountered more and more in present-day technology. Progress in the development of the metals molybdenum, titanium and zirconium has been stimulated because of this need. Molybdenum and titanium are now obtainable in limited quantities and shapes, but zirconium research has not as yet advanced to the point of making that metal readily available. Techniques for producing and fabricating these metals are progressing rapidly, so that within the next few years they should take an important place in industry alongside the other so-called "special metals," such as the stainless steels, superalloys, tantalum and others.

Each of the new metals has properties that make it valuable for certain applications but, of course, each also has its limitations. In the table above, the common characteristics of molybdenum, titanium and zirconium are compared with those of nine other well-known metals.

Molybdenum, which is available commercially,* is particularly noteworthy because of superior strength at temperatures above 1900° F. as compared with the best present-day metals, and for its high modulus of elasticity. It is probable that molybdenum alloys of even more desirable properties will be announced before long. The increased availability of sheet, forgings and fairly massive parts of high molybdenum alloys will enable us to gain the increased efficiency of many processes at high temperatures.

Molybdenum shows outstanding resistance to hydrochloric acid. A decided limitation, however, is the severe oxidation of the metal at red heat and above. Surface coatings that will overcome this drawback are being intensively studied and will probably provide a solution to the problem.

Welding of molybdenum presents problems due to its high conductivity and melting point, and development work in this field is required.

Titanium appears to have a future paralleling that of aluminum. It is more abundantly available in the earths crust than many other commonly used metals. By alloying or cold working, its tensile strength can be increased to 150,000 psi. or more. It is relatively light (about 67% heavier than aluminum, but over 40% lighter than the stainless steels).

The metal is weldable and does not present any unusual fabrication problems. Corrosion resistance is excellent, approximately equal to that of the stainless steels, which makes titanium a highly promising material for industrial atmospheres and possibly for salt-air applications. Titanium development is proceeding rapidly and one large metal-producing company has announced the availability* of limited quantities of titanium in sheet and other forms.

Zirconium development appears to be in its early stages and while the metal is available for special small-

Reprinted from Feb. 1950 issue *Tempil Topics*.

* Names on request.

THE NEW METALS – MOLYBDENUM, TITANIUM AND ZIRCONIUM

COMPARED METALS	Approx. melting pt. °F.	Weight in pounds per cu. in.	Weight in pounds per cu. ft.	Weight ratio**	Expansion Ratio**	Thermal conductivity ratio**	Specific heat ratio**	Tension Modulus in Millions
Magnesium*	1204	.063	109	1.00	1.00	1.00	1.00	6.3
Beryllium*	2345	.066	114	1.05	0.46	1.00	2.10	37
Aluminum*	1215	.098	170	1.56	0.92	1.40	0.86	10
TITANIUM*	3300	.164	284	2.60	0.33	0.19	0.50	17
ZIRCONIUM*	3200	.23	393	3.65	0.19	0.05	0.26	11
Plain high chromium stainless steels	2750	.28	485	4.45	0.42	0.26	0.43	29
Plain carbon and low alloy steels	2700	.286	490	4.50	0.46	0.51	0.43	29
Austenitic stainless steels	2600	.29	500	4.58	0.67	0.17	0.47	28
Nickel*	2650	.32	560	5.13	0.50	0.58	0.42	30
Copper*	1980	.32	560	5.14	0.63	2.50	0.37	16
MOLYBDENUM*	4760	.37	650	6.00	0.19	0.92	0.24	50
Tantalum*	5400	.60	1050	9.70	0.25	0.34	0.14	27

*Commercially pure metals.

**Approximate ratio (near 70°F) Magnesium = 1.

scale uses, it is not being produced in commercial quantities at the present. The metal is 20% lighter than plain carbon and stainless steels but is about 40% heavier than titanium. It is superior to titanium and the stainless steels in corrosion resistance to many media. Future applications appear excellent in view of its high strength, relatively light weight and excellent corrosion resistance, and these attractive properties should spur research and development looking to the production of zirconium on a commercial scale.

Simple Jig Makes Quick Work of Pipe Joints

by T. Barron

POSSIBLY some shop may come across a similar problem to that which confronted the writer on one contract and it is hoped that this jig, or a form of it, may prove of assistance.

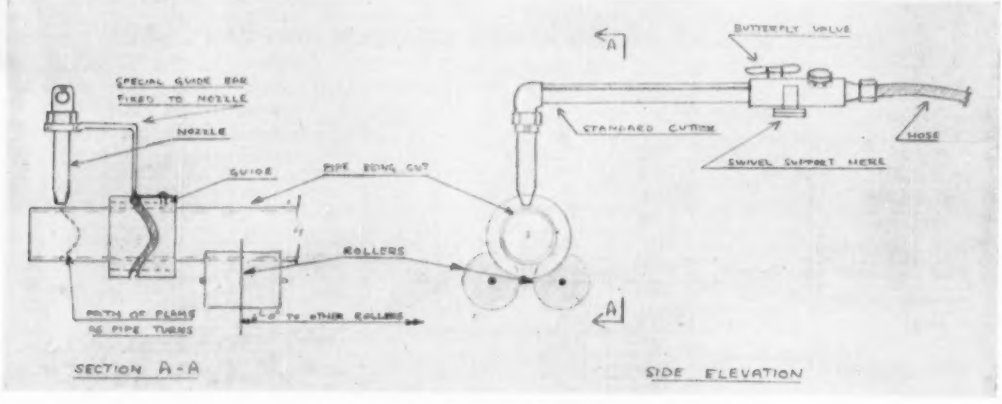
A large number of right-angled joints had to be made in pipework and speed was of great importance—this problem occurred when a number of light bridges were to be site-fabricated from M.S. tubes. The top and bottom chords of the N-girder design used were 2-in. bore tube, as were the compression members. The tie-rods were $^5/_8$-in. diameter bars. The vertical compression members were shaped to fit closely to the chord tubes before arc welding and it was found that the marking and cutting of these by hand was a slow process and accuracy could not be guaranteed at the speed required.

The guide was formed from two pieces of tubing fitted concentrally and welded together, the outer tube being first cut and the pieces moved apart $^3/_{16}$ in. to form the guiding groove. This should be clear from the sketch. A cutter with a butterfly-nut operated valve was found and proved to be a great help enabling the cutting oxygen to be turned off and on as required without the necessity of keeping one hand on the cutter. The guide took the weight of the nose of the cutting torch.

To set up the jig, the guide was slipped over the tube and grub-screwed at a set distance from the root of the required cut. The tube was slowly turned on the rollers by hand during the cutting process and after one or two attempts the operator was able to make a smooth cut. As none of the tubes cut were over 8 ft. long the two sets of rollers were spaced 6 ft. apart on a bench, together with the cutter stand.

It will be found, on trial, that the root of the cut gives a tight butt joint while the tongues run gradually toward a V-joint. The penetration of the welding overcame this as the metal was only about $^1/_8$ in. thick. For larger diameter tubes with similar metal thicknesses this discrepancy will not be so noticeable.

T. Barron, 18 Edith St., Middlesbrough, Yorkshire, England.



Simple jig to cut pipe joints

ABC's of Pipe Cutting

by K. M. Schaefer

ALWAYS select the nozzle and oxygen pressure you would use for steel plate of the same thickness. (See the instruction folder for the blowpipe you are using.) Then adjust the preheat flames to neutral with the cutting-oxygen valve open. The inner cones of the preheat flames should be from $^3/_{16}$ to $^1/_4$ in. in length when the cutting-oxygen valve is open. Hold the blowpipe in your right hand to keep constant control of the cutting-oxygen lever. (See Fig. 1.)

Continue the cut until you reach the top of the pipe, Fig. 3. Keep the nozzle always pointed toward the center of the pipe. When you reach the top, stop cutting and roll the pipe so the place where you stopped is now halfway between the side and top. Then restart the cut as you did before. Stop and roll the pipe until you have completed the cut.

Balance the blowpipe on your left hand, Fig. 2. Begin the cut about half-way between the side and top. Hold the tips of the inner cone close to the pipe and heat a spot about the size of a nickel. When the spot turns bright red and starts to melt, press down the cutting-oxygen lever slowly. Wait until the cut goes through the pipe, then move the blowpipe slowly along the line of cut.

If you move the blowpipe too fast, the cutting jet will

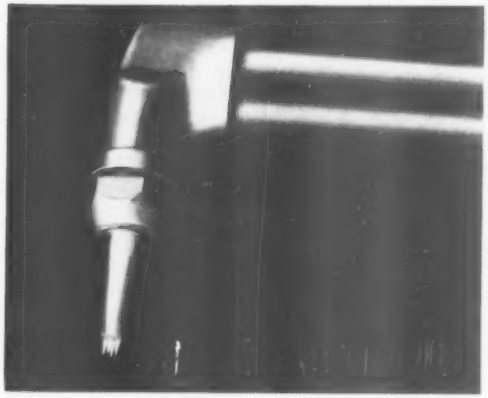


Figure 1

Figure 2

K. M. Schaefer is with The Linde Air Products Co., Indianapolis, Ind.

Figure 3

Figure 4

not go through the pipe and cutting will stop. When this happens, release the cutting-oxygen lever at once, Fig. 4. Reheat the point where the cut stopped to a bright red and restart the cut. If, when you have finished, slag holds the two pieces of pipe together separate them with a sharp rap with a hammer.

What Is Your Welding I. Q.?

THERE is shown below the 1949 Edition questions which were shown at the National Defense Exhibit, Department of the Navy Section, during the October Metal Show in Cleveland. These questions, as before, aroused considerable interest and it is estimated that approximately 4000 people have taken the measure of their Welding I. Q. The questionnaire as before, was compiled by personnel of the Welding Branch of Welding and Electrical Laboratory, U. S. Naval Engineering Experiment Station, Annapolis, Md.

LOW-ALLOY STEELS

What is Your Welding I.Q.?		Yes	No
1.	The use of lime-coated electrodes is mandatory for welding low-alloy steels.		X
2.	All low-alloy steels are susceptible to underbead cracking.		X
3.	For most low-alloy steels the interpass temp. may fall below that of preheating.		X
4.	In welding pressure vessels or tubular shafting when the wall thickness exceeds 3 in., intermediate stress relief is effective to prevent cracking of the weld.	X	
5.	In manual welding thick-walled vessels or tubes, welding with d.-c. power is preferable.		X
6.	The pass thickness of weld metal deposited from low-alloy steel electrodes does not influence ductility.		X
7.	In general the welding technique applicable to a given type mild-steel electrode is also valid for low-alloy electrodes of the same type.	X	
8.	Application of the stress-relief treatment immediately on completion of the weld is mandatory for the highly air-hardening low-alloy steels.	X	
9.	All low-alloy steels are air hardening and therefore, subject to stress-relief treatment.		X
10.	For normalized steels the stress-relief temperature must be higher than that used in drawing after normalizing.		X

SAFETY IN WELDING

		Yes	No
1.	At comparable open-circuit voltage d. c. is more dangerous than a. c.		X
2.	Open-circuit voltages in excess of 50 v. represent potential hazards in welding.	X	
3.	Constant potential welding generators used with resistor banks in series with the arc are the most hazardous.		X
4.	Without the proper protective clothing 80-v. open-circuit voltage, either a. c. or d. c., represents lethal danger.	X	
5.	A leaky acetylene hose may be patched.		X
6.	A handy man should repair a defective oxygen on acetylene regulator.		X
7.	Hydrogen-air mixture is highly explosive in all dilutions ranging from 3:1 to 10:1.	X	
8.	Oxygen is not inflammable; however, oxygen leakage in confined places represents potential explosion or fire hazard.	X	
9.	All compressed gas containers valves must be quickly opened and shut before attaching the regulator.	X	
10.	Copper tubing is a suitable material for manifolding acetylene gas.		X

INSPECTION OF WELDS

		Yes	No
1.	Stereoscopic X-ray views of thick welds reveal the depth and location of the defects indicated.	X	
2.	Magnetic Powder indications are influenced by residual stress.	X	
3.	Lack of fusion, in absence of slag, is seldom revealed by X-ography.	X	
4.	Subsurface defects cannot be readily detected by magnetic powder inspection.		X
5.	Visual examination with an illuminated magnifier is the most practical method for interpass inspection of welds for cracks.	X	
6.	Smoothness of surface renders the applicable methods of surface inspection more dependable.	X	
7.	Ultrasonic method of inspection is applicable to detect defect concentrations in butt joints.	X	
8.	For fillet welds, X-ray and ultrasonic inspection are equivalent.		X
9.	Defect indications by X-ography and serviceability of weldments have been fully correlated.		X
10.	Arc stability recording instruments are not applicable with submerged arc welding.		X

MAINTENANCE WELDING

		Yes	No
1.	Weeping or slow leakage through bronze castings can be stopped by applying a coat of low-temperature bearing alloy.	X	
2.	Joints fabricated by low-temperature torch or furnace brazing are suitable for shear loading only.	X	
3.	Local repairing is practicable on damaged hard-surface overlays on valve disks and seats.	X	
4.	Building up by metallizing is applicable only to rotary shafts.		X
5.	Worn rollers and other heavy equipment can be salvaged by automatic arc welding employing covered electrode wire fed from a reel.	X	
6.	Decisions concerning repair welding or alterations of pressure vessels must be based on rules given in the applicable codes.	X	
7.	Spark testing is a reliable method for identifying the composition of steels.		X
8.	A.-C. power is preferable for the fabrication of intricate machine parts as it produces sounder welds.	X	
9.	Low yield-point weld metal, such as 25 Cr–20 Ni may be used to repair intricate steel machine parts where close dimensional tolerance must be maintained.	X	
10.	Pure nickel, covered electrodes may be used for welding cast-iron engine blocks.	X	

Recondition Banbury Mixers

by H. C. Linde

THE Welding Methods Corp., Dayton, Ohio, has developed a successful procedure for reconditioning Banbury Mixers. This rubber-mixing equipment is subjected to high structural stresses and its surfaces must withstand extremely abrasive conditions, as a result of the relatively high percentage of clays and carbon blacks used in the compounding of the mixtures.

Extensive experimental work and analysis revealed that the principal factors contributing to failures of these mixers consisted of improper materials and techniques used for hard-facing surfaces exposed to high-pressure contact with the materials being mixed. The mixer frames and rotating elements were of Grade B cast steel and the hard-facing materials and application procedures were such that an inferior bond with the base metal resulted.

Figure 1 shows hard-faced mixer rotor, with spalled off pieces, due to poor bonding, displayed on piece of paper at top. Investigation showed that unequal contraction of the base metal and hard-facing alloy in cooling subjected the fusion line to an extreme stress differential. To eliminate this, it was found necessary to apply a chrome-nickel electrode to the base metal, cold working for stress relief in progression and then to apply the hard-facing material. The intermediary

Fig. 1 Pieces spalled off rotor, due to poor bending

H. C. Linde is Supervisor, Technical Sales Department, Dayton District, Air Reduction Sales Co., Dayton, Ohio.

Fig. 2 Rotors hard faced with Airco self hardening and Aircoloy No. 6

Fig. 3 Hard-facing rotor in rotating jig. Welder about to lower helmet and strike arc

chrome-nickel alloy showed a high-bonding affinity for both the base metal and hard-facing material.

After many experiments, 19/9 Stainless-Steel Electrode was found best for the primary pass and a self-hardening electrode best for hard facing the rotor surfaces, with Aircoloy No. 6 Electrode for the lip edges. These materials have been standardized upon. With their use, it has been found practically impossible to produce spalling. Figure 2 illustrates a rotor, the hard-faced areas of which were subjected to planing for twelve hours, with the 8-lb. sledge shown, in straightening. At the end of this time, the hard-faced surfaces showed absolutely no indication of cracking or spalling.

Figure 3 pictures rotor in the process of being hard-faced in turning jig. Note neat, uniform appearance of passes applied. They report that Banbury Mixers rebuilt with these hard-facing materials and returned to service show convincing evidence that their life expectancy can be increased substantially in this manner.

A Fast Repair Helps the Farmer

by L. S. Bowser

FARM equipment usually breaks down only when the farmer needs it most. If the implement shop has no replacement parts in stock, the binder, tractor or planter will be out of action. The crop may be ruined or valuable planting time lost before the farmer can get a new part. But most farm equipment can be repaired by bronze welding. And that is profitable for both the shop and the farmer

Here is how the flange of a tractor roll was bronze welded in less than half an hour. Just as in all bronze-welding jobs, the secret of this good repair was to clean the part thoroughly and line up the broken pieces with the rest of the flange. The edges were beveled to get complete penetration. All the oil, grease and rust were removed from the edges and for a distance of about half an inch back. A file and steel wool were used to do the cleaning.

Bronze welding requires only local preheating to a low temperature. That made it possible to preheat only the flange and the broken section. The broken piece was fitted into the proper place on the flange and held in place with a clamp, as shown in Fig. 2. When several strong tack welds were made the clamp was removed and the welding completed, as shown in Fig. 3. The roll was allowed to cool and the bolt hole was rebored.

L. S. Bowser is connected with The Linde Air Products Co., Boston, Mass.

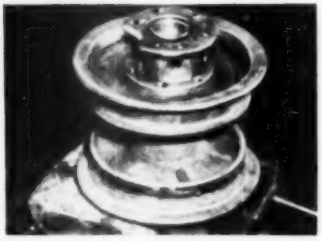


Fig. 1 The edges were beveled and a file and steel wool was used to clean oil, grease and rust from the broken edge

Fig. 2 The broken piece was fitted into the flange and held in place with a clamp

Fig. 3 Several tack welds were made and the clamp removed

the AMERICAN WELDING SOCIETY

activities • related events

Annual Meetings—Metal Congress and Exposition

AMERICAN WELDING SOCIETY, Annual Meeting, Chicago, Oct. 23–27, 1950. J. G. Magrath, National Secretary, 33 W. 39th St., New York 18, N. Y.

American Society for Metals, Annual Meeting, Chicago, Oct. 23–27, 1950. W. H. Eisenman, National Secretary, 7301 Euclid Ave., Cleveland 3, Ohio.

Metals Branch—American Institute of Mining and Metallurgical Engineers. Fall Meeting, Chicago, Oct. 23–27, 1950. E. H. Robie, National Secretary, A.I.M.E., 29 W. 39th St., New York 18, N. Y.

Society for Nondestructive Testing, Annual Meeting, Chicago, Oct. 23–27, 1950. Philip D. Johnson, National Secretary, Skokie, Ill.

Annual Program A.W.S. will be published in July issue Welding Journal.

Metal Congress and Exposition

The 32nd annual National Metal Congress & Exposition—the "Metal Show"—will open in Chicago's International Amphitheatre Oct. 23, 1950, and will run throughout the five week-days, including Friday, October 27th.

The "curtain raiser," as usual, will be the American Society for Metal's annual Saturday and Sunday (October 21–22) Seminar. The 1950 Seminar will cover the highly scientific subject of Diffusion. Many of the country's top metallurgical experts will hold open sessions on Saturday morning, afternoon and evening, and sessions during the morning and afternoon on Sunday.

Announcement has just been made by W. H. Eisenman, Managing Director of the annual Metal Show, and Executive Secretary of the American Society for Metals, that floor plans have already been made available, and that the Exposition's space-assignment committee will meet March 20th.

Sponsoring the 1950 Metal Congress & Exposition in Chicago will be, in addition to the American Society for Metals; the AMERICAN WELDING SOCIETY; Metals Branch-American Institute of Mining and Metallurgical Engineers; and the Society for Nondestructive Testing.

An anticipated attendance of between thirty-five and forty thousand registered Metals Engineers is expected, according to Eisenman.

Executive Committee Meeting

A meeting of the Executive Committee of the AMERICAN WELDING SOCIETY was held in Room 608, Engineering Societies Building, New York City, Jan. 24, 1950, with the following in attendance:

Members: H. W. Pierce, C. H. Jennings, D. Arnott, R. S. Donald, H. O. Hill and T. B. Jefferson.

By invitation: H. Biers.

Staff Members: J. G. Magrath and F. J. Mooney.

Absent: O. B. J. Fraser.

Revisions to Article V, Section 2, 6 and 7 of the Society's By-Laws

The Constitution and By-Laws Committee submitted proposed revisions to Article V, Sections 2, 6 and 7 of the Society's By-Laws.

Article V, Section 7, Refund to a Section—At the beginning of each fiscal year, each Active Section shall receive from the SOCIETY an anniversary payment which shall equal $2.00 for each member but which shall not exceed a total of $100. In addition, at the beginning of each quarter of the fiscal year, each Active Section shall receive 20% of the sum collected in dues during the preceding Quarter from those of its members who are in the grades of Sustaining Member, Member and Associate Member. Each newly organized Section shall receive the anniversary payment on the date of acceptance of organization and on the following October 1st such newly organized Section shall receive the anniversary payment based on membership at that time but less overpayment prorated on a monthly basis for the first fiscal year. At the time of organization of a new Section, returns shall be made on the annual dues of members newly enrolled in the SOCIETY during the six prior months to the date of organization of the Section, unless refund has been paid to another Section for such members. Refunds shall be paid to the Section with which each member is affiliated at the time when refund payments are due.

These proposed revisions were carefully reviewed by the Executive Committee and upon motion, duly seconded, were amended to read as follows:

Article V, Section 2. Minimum Section Membership—Not fewer than 50 members or eligible applicants for membership in the AMERICAN WELDING SOCIETY, in the Sustaining Member, Member and Associate Member grades may apply for authorization for the organization of a new Section.

Article V, Section 6, Requirements of an Active Section—No Section shall be considered active unless it holds at least three meetings during a fiscal year, and has a total paid membership of twenty-five (25) enrolled in the Sustaining Member, Member and Associate Member grades. Any Section whose membership diminishes to below twenty-five (25) members shall be considered an inactive Section. When Sections fail to comply with the above requirements, the National Secretary shall report such facts to the National Board of Directors which shall act upon each case in accord with its merits. A Section that has been disbanded may be reinstated with a minimum of twenty-five (25) members as approved by the Board of Directors based on the merits in each case.

The Executive Committee moved that the proposed By-Laws, as adjusted, be referred to the A.W.S. Constitution and By-Laws Committee for final drafting and submission to the membership-at-large for approval.

Revision to Article XII, Section 3, of the Society's By-Laws

The Constitution and By-Laws Committee submitted proposed revisions to Article XII, Section 3 of the Society's By-Laws.

The Executive Committee reviewed the proposed revisions as submitted by the Constitution and By-Laws Committee, and after adjustment, moved that the revised by-law be referred to the Constitution and By-Laws Committee for final drafting and submission to the membership-at-large for approval. Herewith follows revised wording for Article XII, Section 3 as approved by the Executive Committee.

"Section 3. Membership Committee—A Membership Committee of seven or more members shall be appointed not later than May 1st of each year, to serve from June 1st of that year to May 31st of the following year, whose duty shall be to formulate and execute plans and prepare literature for maintaining and increasing the membership of the SOCIETY. The District vice-presidents shall be ex-officio members of this Committee."

Disposition of Contribution by Harnischfeger Corp.

Harnischfeger Corp., Milwaukee, Wis., under date of Dec. 21, 1949 remitted to the SOCIETY a check in the amount of $50 as a year-end contribution to the activities of the AMERICAN WELDING SOCIETY.

The Executive Committee ruled that this check be part of the current funds of the SOCIETY and not to be placed in the Society's Reserve Funds Account.

A.W.S. Renewal of Membership in The I.I.W. for The Calendar Year 1950

The Secretary stated that A.W.S. renewal of membership in the International Institute of Welding for the calendar year 1950 is now due.

By invitation of A.W.S President Fraser, Howard Biers, a Member-at-Large of the A.W.S. Committee on I.I.W., was invited to appear before the Executive Committee for the purpose of acquainting the Members with the more recent developments of the I.I.W.

Mr. Biers reported that the first meeting of the I.I.W. was held last spring. The purpose of this meeting was to formulate commissions and schedule a program of operations. Final program will not be completed until the next meeting of the I.I.W. which is slated to take place in Paris, France during the period June 5–10, 1950. To date, the only tangible result of the I.I.W. is the publication of a *Bibliographical Bulletin*, for Welding and Allied Processes. This Bulletin, printed in both English and French, contains abstracts and classification of studies and papers relating to welding and allied processes in the world's technical press. Mr. Biers observed that it is the best survey of international literature in the world made to date and recommended that American Universities should become acquainted with this book as prepared by the I.I.W. Committee on Documentation. The I.I.W. has made this book available on a subscription basis.

Mr. Biers stated that all Commissions have been organized with the United States being assigned the Chairmanship of several of these Commissions. The I.I.W. is studying the feasibility of assigning to each Commission a Deputy Chairman who would reside in a European country and would act in the absence of the Chairman.

It was pointed out by Mr. Biers that it is too early to know exactly what tangible results the United States will receive in this project but made mention to the fact that the Institute is much interested in the standardization of American codes, standards, etc. He observed that for continuation of the I.I.W. it is essential that the Institute receive American support.

The Executive Committee voted favorably on A.W.S. renewal of membership in the I.I.W. for the calendar year 1950.

Recommendations for A.W.S. Technical Activities Committee

Appointment of A. M. Setapen as A.W.S. Representative on Section 5—Refrigerating Piping Systems, A.S.A. Committee on Code for Pressure Piping. The Executive Committee upon motion, duly seconded, approved of the appointment of A. M. Setapen as A.W.S. Representative on the above Committee.

A.W.S. Committee Appointments

The Executive Committee approved of the following committee appointments:

(1) Sam J. Walker, Butler Mfg. Co., Kansas City, Mo., to serve on the 1949–50 National Nominating Committee, as representative from A.W.S. District No. 6, in place of Jerry Fiegener who declined appointment to this Committee.

(2) Edgar P. Auler, Taylor Forge and Pipe Works, Cicero, Ill. to serve as Vice-Chairman of the National Convention Committee. At a previous meeting of the Executive Committee of the A.W.S. Chicago Section, Mr. Auler was designated to this position.

(3) K. Walker, Foster Wheeler Corp., Carteret, N. J., to serve on the A.W.S. Program Committee. Messrs. Brekelbaum and Crawford previously declined appointment to this Committee.

(4) Dr. W. D'Orvile Doty, Carnegie-Illinois Steel Corp., Pittsburgh, Pa., to serve on the A.W.S. Welding Journal Committee.

Request for Reduction in Membership Dues for A.W.S. Foreign Members

Requests for reduction in membership dues for A.W.S. foreign members and educational institution members were carefully reviewed by the Executive Committee and upon motion, duly seconded, the Committee Members voted against the institution of any special provision to grant foreign members and educational institution members of the Society a reduction in membership dues.

Membership Status Report for Four-Month Period Ended Dec. 31, 1949

The Chairman reported that for the

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175	325	650	1200	1750
188	338	700	1250	1800
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213	363	800	1350	1900
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four (4) month period Sept. 1, 1949–Dec. 31, 1949, the SOCIETY reported a gain of 598 members as against a loss of 388 members, resulting in a net gain of 210 members. The total A.W.S. membership as of Dec. 31, 1949 was 7401 members. During the first twenty-four (24) days of January, the SOCIETY enrolled 71 new members which included three (3) new Supporting Company enrollments and 113 delinquent members remitted payment of dues.

Decline in Membership Delinquency

It was observed that as of Dec. 31, 1949 the SOCIETY's delinquency was 13.3% as against 17.3% on Dec. 31, 1948.

Book Review Committee

The Educational Committee recommended to the Board of Directors for approval that a letter be distributed to all book publishers advising of the existence and scope of the Book Review Committee. Upon acceptance of any manuscript on welding, the Book Review Committee will send a statement to the publisher that the manuscript has been reviewed by their Committee and will authorize the publisher to print a statement to this effect in the book. There will be no charge to the publisher for this review service. The Book Review Committee will also have jurisdiction over engineering drawing books.

The Executive Committee voted favorably on this standard operating procedure for the Book Review Committee, which is a Subcommittee of the Educational Committee.

Solicitation of Contributions by Sections

At the Executive Committee meeting held on Nov. 3, 1949, the Secretary reported that he had received two complaints from representatives of organizations to the effect that they received solicitation for funds for Section activities from Sections remote from their headquarters and purely on the basis of their company having sold their product in that area. These parties felt that in supporting their own local Section, they benefited therefrom and were meeting a legitimate obligation, but did not feel that the same always applied in the instance of remote Sections.

The Executive Committee, at that meeting, felt that the Ruling adopted by the Board of Directors in June, 1945 entitled "Solicitation of Contributions by Sections" sufficiently covered A.W.S.' policy in this matter and accordingly instructed the Secretary to communicate with the Chairman of all Sections calling attention to this Ruling. The Ruling states in part as follows:

"The National Board of Directors, while conscious of the needs and aspirations of the Sections of the AMERICAN WELDING SOCIETY, nevertheless, wishes to discourage *too heavy* solicitation and feels that such contribution should be confined generally to meetings expense, including refreshments."

The Executive Committee after reviewing the statement amended the Ruling Adopted by the Board of Directors in June, 1945 to include the following statement:

"Section solicitation of contributions shall be confined to concerns located within the section's limits or representatives of national firms within their section's limits. Mailing to be made at local level."

Pressure Vessel Research Bulletin Available

The AMERICAN WELDING SOCIETY has undertaken to distribute copies of Bulletin Number 4 of the Welding Research Council Bulletin Series to those who desire it. This Bulletin covers two important reports by the Pressure Vessel Research Committee of the Council. One of these deals with Testing Pressure Vessels, by F. G. Tatnall. This review was prepared to assist investigators interested in mechanical testing, experimental stress analysis and apparatus and pressure vessel research.

The second report is on Effect of Welding on Pressure Vessel Steels, by A. F. Scotchbrook, L. Eriv, R. D. Stout and B. G. Johnston. This report gives the results of a study using the Lehigh slow-notched bend test to determine the effects of welding on as-received and prestrained plate. Effects of different heat inputs in welding, the effects of plate thickness, of carbon content and deoxidation practice and of heat treatment after welding.

Copies of this Bulletin are available at 50¢ each through the AMERICAN WELDING SOCIETY, 33 West 39th St., New York 18, N. Y.

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Have superior physical qualities — ideal for welding heavy sections that must withstand severe shock and abuse.

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- ***For aircraft and similar steels . . .*** has wide range of properties under heat treatments... *P&H#21.*

Withstand high amperages and have high deposition rate. Operators burn more rod per hour, weld faster at lower costs.

These rods operate with stable arc on AC or reverse-polarity DC. Other money-saving features are: Elimination of underbead cracking. Low hydrogen content for successful enameling. Little or no preheating. Minimum spatter. Excellent appearance of weld... freedom from surface holes. Order from your P&H representative or local P&H distributor. Send coupon for detailed information.

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PERSONNEL

Theisinger Made Regional Manager

The appointment of Dr. William G. Theisinger as regional manager of sales for Lukens Steel Co., with headquarters in Houston, Tex., was announced recently by J. Frederic Wiese, vice-president in charge of sales. Dr. Theisinger has been manager of technical sales, with headquarters in Coatesville, for the last four years. In his new position, Dr. Theisinger will supervise the activities of Lukens district sales offices and sales representatives in 12 southern states, from South Carolina to California.

Dr. Theisinger joined Lukens in 1935 as a welding and metallurgical engineer, becoming director of welding research in 1941. A native of Carlisle, Pa., he was graduated from Harvard University from which he received the degree of Doctor of Science.

Dr. Theisinger has also served at Harrisburg (Pa.) Steel Corp. as assistant chemist; with the Board of Transportation of the City of New York, in the development of welding inspection; and with Western Pipe & Steel Co., San Francisco, as consulting engineer on high-amperage automatic welding.

He is a member of the AMERICAN WELDING SOCIETY, the North American branch of the Newcomen Society of England, the Franklin Institute and the Harvard Club of New York.

Air Reduction Appoints Saacke Safety Engineer

Air Reduction Co., Inc. has announced the appointment of F. Carl Saacke as safety engineer.

Mr. Saacke will be responsible for carrying out policies of the Air Reduction organization which will lead to more complete safety for its employees and the general public.

Specifically, he will review equipment used and sold by Air Reduction for safety factors and will be concerned with plant safety programs and employee interest in these programs.

As a member of the Committee on Safe Practices, Mr. Saacke will be charged with carrying out this committee's policies, while serving as the investigating member of the group.

A graduate of Cornell University, Mr. Saacke joined Air Reduction in 1931 as a jr. engineer. Four years later, he was promoted to engineer and then to asst. research and development engineer. In 1946, he became research and development engineer, a position he held until his recent promotion.

Mr. Saacke will conduct his activities from the Air Reduction general offices at 60 E. 42nd St., New York 17, N. Y.

Changes in Lincoln Electric Sales and Engineering Staff

C. L. Stocker has assumed sales and engineering responsibilities for Lincoln in the San Francisco area. The office for this district is located at 1303 Stanford Ave., Emeryville, Calif. Stocker has been active in various parts of the country in the development of welding for the past 20 yr. He started with Lincoln in 1930 and has been district manager of the Seattle area since 1943. The welding engineering staff of the Emeryville office has recently been increased by the addition of M. F. Yale and T. Nichol—both recent engineering graduates with several years service in the armed forces.

A. L. Patnik has been given responsibility for Lincoln welding engineering in the Seattle district, with offices located at 1914 Utah Ave., Seattle, Wash. Patnik has been with Lincoln since his graduation from Ohio State University in 1950 and, except for his term in service, has been active in the development of welding on the West Coast.

Melvin O. Monsler New Sales Manager of P & H Welding Division

Harnischfeger Corp., Milwaukee, manufacturer of P & H Arc Welders and Welding Electrodes, announces the appointment of Melvin O. Monsler as sales manager of the P & H Welding Division. Mr. Monsler, who is widely known in welding circles, has been associated with P & H for 12 yr., serving for 4 yr. as assistant sales manager of that division and 1 yr. as Welding Product Service Engineer. Much of Mr. Monsler's practical experience in all matters of arc welding was gained in P & H's own welding shops where he was a welder and assistant to the superintendent. Prior to joining P & H he was an instructor in Welding and Shop Procedure, Milwaukee School of Engineering.

Green Made President A.B.S.

Walter L. Green was elected President of the American Bureau of Shipping on Jan. 31, 1950, succeeding J. Lewis Luckenbach who was elected Chairman of the Board of Managers, at the annual meeting of the national ship classification society. He had been Vice-President since January, 1947 when he rejoined the Bureau after a period of participation in the war shipbuilding effort. He resigned from the American Bureau in 1939 to associate himself as Vice-President with the Seattle-Tacoma Shipbuilding Co., a Todd Shipyards Corp. affiliate, and later was transferred to the New England Shipbuilding Corp. of the Todd group as Vice-President and General Manager. He started his career in the shipping industry in 1913 with the Luckenbach Steamship Co., continuing with them on both the Atlantic and Pacific coasts until 1937 when he resigned to join the American Bureau.

Mr. Green is a member of the Welding Research Council, the AMERICAN WELDING SOCIETY and the Society of Naval Architects and Marine Engineers.

Brown Elected Vice-President of A.B.S.

David P. Brown, Chief Surveyor of the American Bureau of Shipping, was elected Vice-President on Jan. 31, 1950, succeeding Walter L. Green who was elected President at the annual meeting of the Bureau.

Mr. Brown was appointed Chief Surveyor of the American Bureau of Shipping on July 31, 1947, succeeding David Arnott who has retired from active duty.

He has spent his entire career in ship classification work, having joined the Bureau in 1921. For the greatest part of this period he has been in charge of the hull technical work as an assistant to the

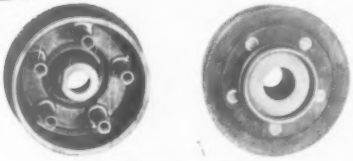
EASY-FLO adds cost-cutting strength to the new Indian lightweight frame

HANDLEBAR
EASY-FLO brazed in approximately 40 seconds

Indian Motorcycle Co. is one of many manufacturers who have found—(1) that EASY-FLO brazed construction satisfies all strength requirements—(2) that EASY-FLO brazing is naturally fast and economical—(3) that production can be stepped up to any required volume by using a fast heating method and a set-up that includes preplacing the alloy—(4) that far less finishing is required. Parts pictured are from the 1950 lightweight model. Tubing is AISI 4130 chrome-molybdenum steel. All tubular joints are induction brazed with rings of EASY-FLO wire preplaced.

COMPLETE FRAME ASSEMBLY
EASY-FLO brazed—100 per hour

FORK TUBES
These tubes form the front fork and act as hydraulic shock absorbers. Joints must be leak-tight as well as strong. The EASY-FLO joint has withstood a load of 16,000 pounds.



CLUTCH DRIVER
Studs are EASY-FLO brazed, 30 drivers per hour, 5 studs each. Front and back views show complete EASY-FLO penetration.

WHAT WILL *EASY-FLO* BRAZING DO FOR YOU? If you join metals—ferrous or non-ferrous—it is fairly certain that EASY-FLO low temperature silver alloy brazing will speed up production and cut costs on part or all of this work. To find out where and how, write or call and ask us to send a service engineer. He'll demonstrate EASY-FLO brazing and discuss its application to your work. There's no obligation to you for this service.

BULLETINS 12-A, 15 AND 17 will give you EASY-FLO facts in print. Write for copies today.

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Chief Surveyor. He descends from a long line of American shipbuilders, his father having been Vice-President and General Manager of the Bethlehem Shipbuilding Corp. up until shortly after World War I.

Mr. Brown was graduated from Massachusetts Institute of Technology in 1920, in the department of Naval Architecture and Marine Engineering. During his career with the Bureau he has served on numerous committees in the industry, among which are the Special Technical Subcommittee in the Preparation of the United States Delegation proposals, to the 1929 and 1948 International Safetyof Life at Sea Conventions; the Subcommittee which was appointed under the Board of Investigation originated in 1943 by the Secretary of the Navy to Inquire into the Design and Methods of Construction of Welded Steel Merchant Vessels; and the Working Subcommittee of the Ship Structure Committee which is now continuing the work of this Board under the direction of the Secretary of the Treasury. He is a member of the Society of Naval Architects and Marine Engineers as well as the AMERICAN WELDING SOCIETY.

James I. Banash to Receive Morehead Medal for 1949

The 1949 James Turner Morehead Medal will be awarded to James I. Banash, Consulting Engineer, Chicago, Ill. He is receiving the medal for his many years of stimulating inspiration, guidance, and encouragement of the acetylene industry toward higher safety achievements. The presentation of the Medal will be made at the opening luncheon of the Annual Convention of the International Acetylene Assn. which is to be held at the Fairmont Hotel, San Francisco, Calif., on Monday, March 27, 1950.

The Morehead Medal is awarded annually by the International Acetylene Assn. to the person or persons who, in the

judgment of its officers and board of directors, have done most to advance the industry or the art of producing or utilizing calcium carbide or its derivatives, the most important of which is the gas, acetylene.

The medal was established by John Motley Morehead in 1922 in honor of his father James Turner Morehead, who sponsored the experiments leading to the discovery in 1892 of the electric furnace method of producing calcium carbide. Since then the medal has been awarded

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annually to those who have made outstanding contributions to the acetylene industry.

Mr. Banash was graduated from Massachusetts Institute of Technology with a degree in electrochemistry. After graduation he continued at M.I.T. for a year as an instructor.

He was with the Underwriters' Laboratories in Chicago for 12 yr. and became head of the Casualty Department. He is an internationally known authority on compressed gases. For many years he has specialized in their safe application and in fire and accident prevention in their relation to the physical and chemical sciences. Mr. Banash is widely known as an author and lecturer, and has achieved special prominence for his work in connection with the mechanical aspects of controlled atmospheres of high oxygen content, especially as applied to oxygen therapy.

Mr. Banash's activities in connection with promoting safety practices were rewarded in 1932 when he was elected President of the National Safety Council. During recent years he has been a consulting engineer in Chicago. He is the consulting engineer for the International Acetylene Assn., and an active member of many engineering and research societies.

Crucible Steel Appointment Announced

Appointment of David Kirk Stuart as Manager of the Pittsburgh Branch of the

Crucible Steel Company of America was announced by W. H. Wiewel, Vice-President in Charge of Sales.

Mr. Stuart will fill the position left open by the promotion of John S. Billingsley to Central Sales Manager on Aug. 17, 1949.

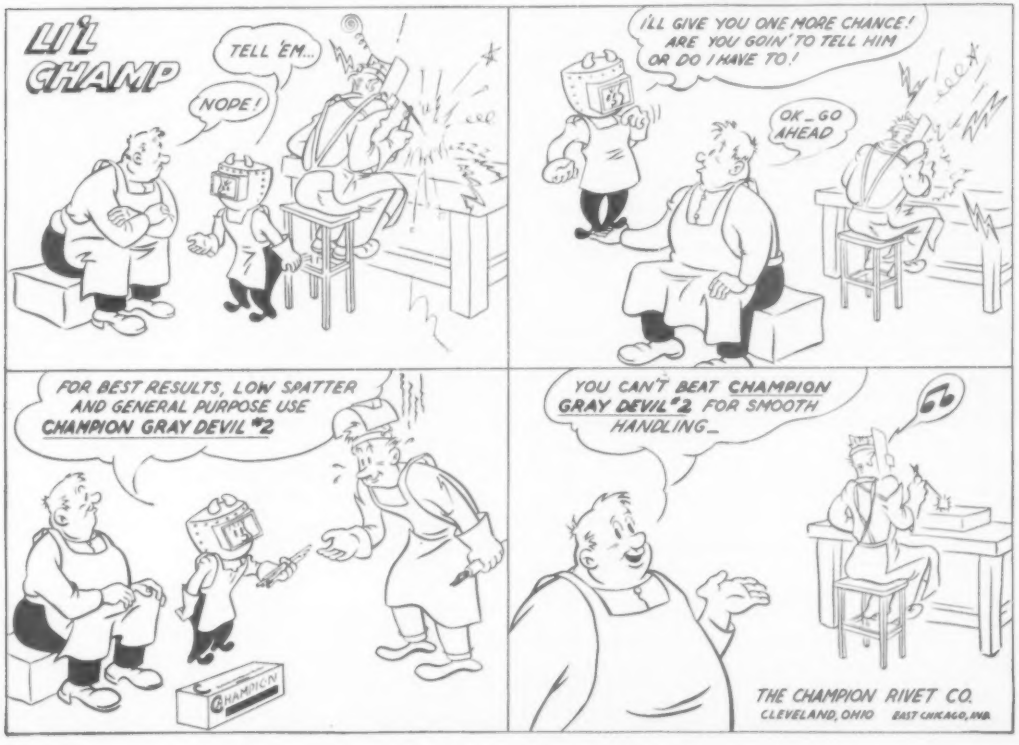
Associated with Crucible since 1933, Mr. Stuart was first employed at the company's Park Works, and in 1935 was transferred to Pittsburgh Branch Sales.

Mr. Stuart is a native of Youngstown, Ohio, and a graduate of Williams College Class of '31.

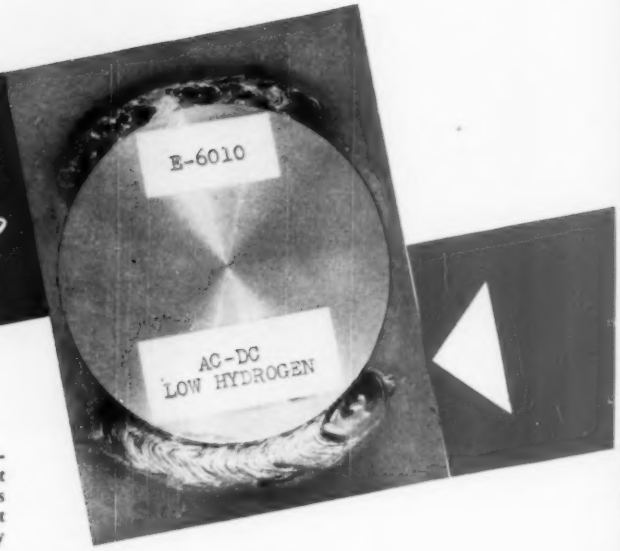
Cummiskey Promoted

The appointment of Ed F. Cummiskey, Arlington Heights, Ill., as Factory Representative, was announced recently by Tweco Products Co., Wichita, Kan.

Mr. Cummiskey will have charge of sales and promotional activities for Tweco in the four state area of Illinois, Indiana, Michigan and Wisconsin. Before joining Tweco, Mr. Cummiskey was in the sales and advertising department of the Do-All Corp. He served for 29 months overseas with the Army as an official Army newsreel cameraman, and is a member of the American Welding Society.


LIL CHAMP
TELL 'EM...
NOPE!
I'LL GIVE YOU ONE MORE CHANCE! ARE YOU GOIN' TO TELL HIM OR DO I HAVE TO!
OK - GO AHEAD
FOR BEST RESULTS, LOW SPATTER AND GENERAL PURPOSE USE CHAMPION GRAY DEVIL #2
CHAMPION
YOU CAN'T BEAT CHAMPION GRAY DEVIL #2 FOR SMOOTH HANDLING_
THE CHAMPION RIVET CO.
CLEVELAND, OHIO EAST CHICAGO, IND.

Welding Hardenable or Sulphur-bearing Steels?



1. Fewer structural failures from underbead cracking—Ordinary electrodes deposit a large amount of hydrogen in weldments on hardenable steel. This produces underbead fissures *not* generally apparent in routine inspection, which in turn causes early structural failures in service. General Electric *low-hydrogen* rods have a special coating which materially reduces the amount of hydrogen deposited, thereby largely eliminating the basic cause for such failures.

2. Better mechanical properties—Laboratory comparisons between these low-hydrogen electrodes and class E6010 electrodes show the former to possess higher tensile and yield strength, better elongation, and *higher impact* at both room and sub-zero temperatures.

3. Welds can be successfully enameled without heat treatment—as has been actively demonstrated on both a laboratory and production basis.

4. Materially improved operating characteristics—G-E low-hydrogen electrodes are extremely flexible in application, with either a-c or reverse polarity d-c; spatter is minimized, deposition efficiency is high, penetration is adequate but not excessive.

There is little or no tendency for surface holes to occur in metals of relatively high sulphur content—and in all cases the finished weld offers an excellent appearance. (Note lower bead in photo above.)

THESE ARE THE G-E "LOW-HY FAMILY"

W-32 is the "father" of the line, having been offered since 1945. A new, greatly improved version was recently introduced—and this performance-proved electrode is now listed at a new, attractive price.

W-60, W-61, W-62 are three new additions, with recommended applications as follows:

W-60—For welding hardenable steels where hazards of underbead cracking are to be eliminated.

W-61—For a wide variety of low-alloy, "high-tensile" steels.

W-62—For use on steel castings and for producing weld deposits having high impact properties at subzero temperatures.

AND THESE OTHER G-E ELECTRODES CAN DO AS MUCH FOR OTHER WELDING JOBS

Mild-Steel and General-Purpose Electrodes—This group of 9 types is headed by W-28, a new general-purpose, all-position rod with an unusually stable arc that produces welds of superior appearance, at high speeds, with minimum convexity. Other electrodes in this group are available specifically for horizontal, vertical, or over-head welding, etc. **Stainless Steel Electrodes**—27 types (16 for d-c, and 11 for a-c or d-c) make this one of the most complete stainless lines available. Each type is keyed to specific AISI code numbers for easy selection. Special, double-carton packaging protects the rod against moisture as well as providing extra protection against transit and storage damage.

Cast-Iron, Hard-Surfacing, & Phosphor-Bronze Electrodes—Herein are some of the more recent additions to the G-E electrode line; W-2075 for making machinable welds on cast-iron; W-94 for abrasion-resistant, hard-surfacing applications; and W-70 for phosphor-bronze welding. They are exemplary of G. E.'s welding laboratories' constant search for better electrodes, improved equipment, and more efficient welding processes.

HERE'S WHY G-E LOW-HYDROGEN ELECTRODES WILL MEAN MONEY IN YOUR POCKET

HERE'S WHAT USERS FIND WITH G-E "LOW-HY" ELECTRODES

Production had virtually stopped at a Pennsylvania machinery manufacturer's plant because cracks were developing in weld-fabricated steel parts. A rush shipment of W-32 from our Philadelphia distributor eliminated the cracking and had them back in production the same afternoon.

Arc welding in general and W-32 electrode in particular played an important part in fabricating this ram or slide for a 200-ton, straight-side crank press. Welded construction with W-32 was used extensively throughout the entire press.

A mid-western transformer manufacturer now swears by W-32 after finding that it completely eliminated a severe cracking and porosity problem in the fabrication of transformer tanks.

You can order these low-hydrogen electrodes from your G-E Arc-welding Distributor today. And ask him for your copy of the new pocket-sized electrode catalog, GEC-482. ***Apparatus Department, General Electric Company, Schenectady 5, N. Y.***

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"A-C or D-C . . .
there's G-E Arc-welding Equipment for Every Application!"

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GENERAL ELECTRIC

NEW LITERATURE

Ampco Welding News

Pistons overlaid with Phos-Trode for better service, metal spraying pump runner shafts with Ampco-Trode and other articles of helpful information are included in the first quarter edition of the Ampco Welding News. A copy of this publication is yours upon request. Write Ampco Metal, Inc., Milwaukee 15, Wis.

Economy of Mechanical Tubing

A new bulletin on mechanical tubing is announced by The Babcock & Wilcox Tube Co. It describes ways in which increased production, lower manufacturing costs and short cuts to improved design may be reached by taking advantage of an unusual service embracing the complete range of steel tubing available to industry. This includes seamless, as well as welded, tubing, hot-finished or hot-rolled, cold-drawn or cold-rolled, in carbon, alloy and stainless steel grades, in various finishes, and heat treated for optimum ease of machining, joining and forming operations. The bulletin also shows how purchasing problems may be simplified.

Bulletin TB-324, is available on request to The Babcock & Wilcox Tube Co., Beaver Falls, Pa.

Babcock & Wilcox Tube Co. Reference Table

A linear conversion table for handy reference by engineers who frequently wish to convert inches and fractions of inches into decimal parts of a foot has been printed by The Babcock & Wilcox Tube Co. The table is suitable for many purposes in addition to those encountered in the application of steel tubing, the company says.

Known as TDC-110 the table is arranged on a single card and is available free to interested parties upon request from the home office of The Babcock & Wilcox Tube Co. at Beaver Falls, Pa.

Steel and Alloy Plate Fabrication

Designed mainly for engineering personnel, this brochure offers a pictorial story of the fabrication of steel and alloy tanks and pressure vessels. Stainless steel, monel, nickel, copper, aluminum, Hastelloy and clad steels are among the corrosion resistant alloys presented. Also of special interest are comprehensive corrosion data charts.

Nooter Corp., 1400 S. Second St., St. Louis 4, Mo.

Radiographic Materials

A new, 16-page catalog of materials for industrial radiography, published by the Eastman Kodak Co., describes films for use with X-ray equipment of varying kilovoltage and with specimens of varying thickness and density. Information on relative speeds and contrast of different x-ray film emulsions is provided in a handy chart to enable the radiographer to quickly select the particular material best suited to his needs.

Additional information is provided on the use of intensifying screens. The catalog is available without charge from the X-ray Division, Eastman Kodak Co., 343 State St., Rochester 4, N. Y.

Handling, Storing and Transporting Aluminium and Its Alloys

In this new edition of *Information Bulletin No. 15* the subject has been treated so as to broaden its application to suit the many and varied uses of aluminium today. After a description of the characteristics of the materials in relation to general conditions of handling, storing or transport, these subjects are treated in turn; and in its logical place between handling and storing, there is a section on methods of protection such as by greases and oils, strip lacquers and painting. Brief concluding paragraphs deal with the important question of identifying stock (since aluminium and its alloys all have similar appearance) and with segregation of scrap in order to take full advantage of the high recovery value of aluminium base materials of specified composition.

The Aluminium Development Assn., 33, Grosvenor St., London, W.1, England.

Welding Alloy for Aluminum

A new two-color descriptive folder on one of the most outstanding developments in aluminum welding metallurgy is available from Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

Known as EutecRod 190, this thin-flowing alloy for lap, corner and square butt joints on aluminum avoids the melting of thin sections, by bonding at approximately 150° below the melting point of aluminum.

The folder includes procedural and technical data, and a useful list of alternate Eutectic Alloys for the welding of aluminum sheet to aluminum casting, joining aluminum to other metals, joining and filling with lead-free alloys and arc welding of aluminum.

Simply send a card to the above address, asking for Form Eu-31.

Residual Stresses in Metals

The 1949 A.S.T.M. Edgar Marburg Lecture *Residual Stresses in Metals* by Dr. William Marsh Baldwin, Jr., Research Professor and Director, Metals Research Laboratory, Department of Metallurgical Engineering, Case Institute of Technology, Cleveland, Ohio, has just been published in the form of a 48-page, profusely illustrated, booklet.

The lecture covers the fundamental differences in the mechanisms by which residual stresses are developed by cold-working operations such as rolling, drawing, extrusion, etc.; by heat treatment and by casting and welding. Also discussed are the experimental methods used to evaluate residual stresses; various residual stress patterns found in fabrication; effects of residual stresses and methods for the elimination of residual stresses.

Copies of this 48-page booklet, paper cover, can be procured from American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., at $1.00 each.

Low Temperature Welding Booklet

Complete data on several new products are presented for the first time in a revised edition, just published, of the 32-page, pocket-size combination low-temperature welding handbook and catalog offered by All-State Welding Alloys Co., Inc., of 273 Ferris Ave., White Plains, N. Y.

This illustrated booklet lists all the All-State rods and fluxes, including several new items. It contains tables of characteristics, full application information and helpful hints of general interest to workers in the metal-joining industries.

Among the new products described are a General Purpose Steel Electrode, a Very High-Alloy Steel Electrode and a Phosphor Bronze "A" Electrode for Arc Welding, a Silver-Bearing Copper Welding Alloy for gas welding and a line of brazing alloys especially packaged for the service trades.

Flash Butt Welding

Advantages of flash butt welding by controlled techniques and typical product applications are shown in a new fully illustrated 20-page booklet just published by The American Welding and Manufacturing Co., Warren, Ohio. Products and subassemblies ranging in size from 4 to 100 in. in diameter and up to 16 miles in length are described. Featured are copper, aluminum, carbon steel, superstrength alloys, forgings and cast iron as metals which have been successfully flash-butt welded into such products as rings for jet aircraft engines, wheel bases and rings for earthmoving machinery, railroad car accessories, petroleum storage tanks, motor and generator shells and frames, engine housings and cyclotron magnet coils.

(*Continued on page 364*)

NEW LINCOLN "TUNGWELD"
Shows Exceptional Resistance to Wear

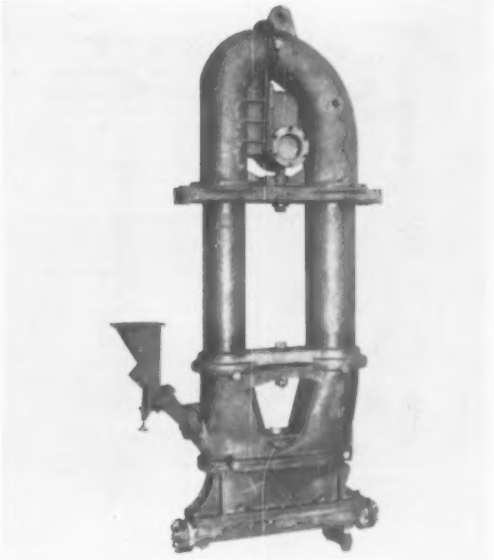

Fig. 1. Wheeler Fluid Energy Reduction Mill, jet type, approximately 400 mph. system velocity. Feeding of ¼" diameter aggregate causes abrasion on inner chamber walls.

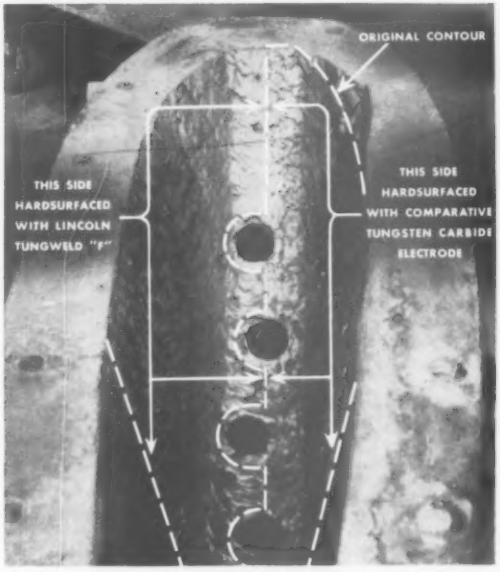
ORIGINAL CONTOUR
THIS SIDE HARDSURFACED WITH LINCOLN TUNGWELD "F"
THIS SIDE HARDSURFACED WITH COMPARATIVE TUNGSTEN CARBIDE ELECTRODE

Fig. 2. Lower half of grinding chamber for C. H. Wheeler Fluid Energy Reduction Mill. Shows condition of hardsurfacing after processing 75 tons of aggregate.

By O. A. Wurtenberg, Design Engineer
The C. H. Wheeler Manufacturing Co.
Philadelphia, Pa.

TO provide our customers with the longest possible equipment life, continuous research is being done on different hardsurfacing materials. Of the types of hardsurfacing electrodes tested, the tungsten carbide type appear to produce the best wear resisting results. In recent comparisons particularly, the Lincoln "Tungweld F" has shown greater resistance to abrasion than all other types of hardsurfacing electrodes compared in our research test runs.

In a recent test, the reduction chamber of a cast alloy steel fluid energy reduction mill was hardsurfaced with two similar (tungsten carbide) types of electrodes. (Fig. 2). One-half was hardsurfaced with Lincoln "Tungweld F" and the other half of the chamber faced with a comparative tungsten carbide electrode. After pulverizing tons of ore, the unit was disassembled and inspected for wear. The results are shown in the photographs above. The area surfaced by the comparative tungsten carbide electrode required 12 pounds of additional electrode to build it up to the original shape. The area surfaced by "Tungweld F" showed some wear but there was sufficient metal left to withstand an estimated 33⅓% additional tonnage of ore processing before any resurfacing would be necessary.

To us, these test results are important. They indicate how we can improve the operating factor of our mills by extending the life of the wear area.

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THE LINCOLN ELECTRIC COMPANY
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LINCOLN

NEWS OF THE INDUSTRY

Twenty-First Annual Purdue Welding Conference, May 3–4, 1950

Three activities going on concurrently:

1. Technical Sessions—Purdue Memorial Union Building. With the assistance of the adjacent sections of the AMERICAN WELDING SOCIETY, excellent speakers have been obtained to present highly interesting papers. Programs which will be mailed as soon as printed will include:

C. B. Voldrich, Chief Welding Engineer, Batelle Memorial Institute, "New Developments in the Welding of Aluminum."

H. E. Gannett, Electrical Engineer, C. B. and Q. R. R., "Progress in Welding on Railroads."

W. R. Plummer, Sales Manager, Progressive Welder Co., "Resistance Welding in the Management of Design and Production."

Van Rensselaer P. Saxe, Engineer, Baltimore, Md., "Economical Design of Welded Buildings."

Clyde G. Bassler, Taylor Winfield Representative, Chicago, "Power Problems of Resistance Welding in the Small Shop."

Harry C. Boardman, Chicago Bridge and Iron Co., "Engineering and Code Requirements upon Which the Designs of Unfired Pressure Vessels Are Based."

Professor R. G. Sturm and Staff, Purdue University, Department of Engineering Mechanics, "Rigorous Comparison of Welded and Forged or Cast Structures in Regard to All Stresses."

2. Exhibits of Equipment and Accessories—Purdue Field House. Better exhibits and more space than ever. No limit on number or size. Open two full days as well as evening of May 3rd.

3. Advanced Courses of Instruction in Welding Techniques—Purdue Field House. Classes will alternate between oxyacetylene and electric arc subjects. Instructors have been secured to show just how to do it right. Certificates will be awarded for attendance.

Oxyacetylene Welding: (1) High-Temperature Soldering, (2) Brazing Under Special Conditions, (3) Sheet and Fender Work, (4) Small Size Pipe, (5) Die Cast White Metal, (6) Cast Iron, (7) Hand and Machine Cutting and (8) Powder Flux Cutting of Stainless Steel.

Electric-Arc Welding: (1) Stainless Steel, (2) Overhead and Special Verticals, (3) Pipe, 3 to 10 in., (4) High Carbon and Spring Steel, (5) Hard Facing, (6) Cast Iron, (7) Inert-Gas-Shielded Arc and (8) Submerged Melt Welding.

For further information write C. E. Martin, Chairman, or R. W. Lindley, Secretary, Purdue Welding Conference, Department of General Engineering, Purdue University, Lafayette, Ind.

Ohio State Welding Conference

The welding engineering department at Ohio State University has announced completion of the program for the 11th meeting of the Ohio State Welding Engineering Conference.

Some 300 engineers, designers and production supervisors from Ohio and neighboring states are expected to attend the campus meeting Friday and Saturday, April 14 and 15. This year's conference theme is "Economy in Design and Production."

First day of the program will be devoted to papers on design for welding, with economy in design the keynote. W. R. Plummer of the Progressive Welder Co., Detroit, will present a paper "Design for Resistance Welding," and William J. Phillips, Director of the Product Development Dept., Steel Founders' Society, Cleveland, will speak on "The Design of High-Quality, Low-Cost Parts for Industry." A. T. Waidelich, Vice-President and Manager of the Research Division, The Austin Co., Cleveland, will talk on the "Analysis of an 80-ft. H-Section Welded Truss."

On Friday evening, April 14, the Columbus Section of the AMERICAN WELDING SOCIETY will be the host for a dinner meeting of the conference at the Fort Hayes Hotel. The featured speaker will be Dr. Finn Jonassen, Technical Director of the Committee on Ship Steel of the National Research Council, Washington, D. C. Dr. Jonassen will present a paper outlining the more recent advancements of welding research and point out the industrial applications possible from these recent gains in basic information.

Second day of the program is centered on production methods. E. C. Brekelbaum, Executive Chief Engineer, Harnischfeger Corp., Milwaukee, will speak on "Coordination of Engineering and Production in the Manufacture of Welded Products," and Arthur B. Tesmen, Development Engineer, North American Phillips Co., New York, will present a paper on the use of contact electrodes. G. C. Kiefer, Associate Director of Research, Allegheny Ludlum Steel Corp., Brackenridge, Pa., will present a paper, "Welding of Stainless Steels," and Lew Gilbert, editor of *Industry and Welding*, will deliver a paper titled "Maintenance Welding."

Informal luncheons are planned on the campus for both days of the conference. Downtown headquarters for the conference will be the Fort Hayes Hotel, and conference visitors should send their room reservations directly to the Fort Hayes. Reservations for the conference can be made by writing the Department of Welding Engineering, Ohio State University, Columbus 10, Ohio.

International Mechanical Engineering Congress

Organized by Trade Associations representative of engineering manufacturers in the Scandinavian and Western European countries, this Congress provides an international meeting place for engineers for the purpose of discussing Papers prepared by men with day-to-day industrial experience rather than a bias toward the purely scientific approach.

In 1949, at Paris, delegations from 16 countries participated in a full program which included not only papers read on the subject of "Production Efficiency," but also visits to industrial undertakings in France.

For the Third International Mechanical Engineering Congress to be held at Brussels, Sept. 18–23, 1950, the Organizing Committee has selected "Quality" as the theme. Papers dealing with specific aspects of this theme, have been invited from various European experts and the activities of the participants at this year's Congress will include visits to some of the principal manufacturing plants in Belgium.

The customary detailed program listing the titles of papers with names of those presenting them and full information, with application forms, will be available from: The British Engineers' Assn., 32 Victoria St., London, S. W. 1.

Research on Metal Removal

As part of its extensive research program, Steel Founders' Society of America, Cleveland, Ohio, has initiated a special project directed to investigating and evaluating all known information on the removal of excess metal normally developed in the production of steel castings.

While there have been noteworthy advances in recent years, the project recognizes the limited nature of existing data on the varying methods of metal removal for gates, risers, feeding pads, fins and other minor protuberances normally encountered. In seeking more complete comparative information based on actual operating experience, restudy of all established methods will be made, together with independent investigation of latest developments in the field.

Experimental studies are being carried out in a selected steel foundry, with the cooperation of a recognized university engineering and research organization, according to F. Kermit Donaldson, executive vice-president of the Society.

Scope of the research project is being extended through industrywide cooperation. Member foundries are contributing individual experience records and pooling

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information on equipment and suggestions on possible design changes or new equipment. The project is being carried out under direction of Charles W. Briggs, technical and research director.

Airco Canadian Subsidiary

John A. Hill, president of Air Reduction Co., Inc., of New York has announced that the name of its Canadian subsidiary company, G. D. Peters & Company of Canada Limited, has been changed to Air Reduction Canada Limited. The management of the company will remain in the capable hands of Hugh Chambers who has headed the Canadian operation for nearly 30 years, and the products and policies that have earned an enviable reputation for the company will remain unchanged.

New Classification System for the Metallurgical Field

Until now, no thorough analysis of the subject matter in metallurgy has been available.

With the recent classification outline, developed by the American Society for Metals, in cooperation with the Special Libraries Association, metallurgical information in all printed or recorded forms can be easily and quickly found, and accurately classified as to processes, properties and materials. When used with a special punch-card system the classification provides for as many as 181,000 different index headings on metallurgical information.

The new classification system is designed to serve both librarians and metallurgists in a variety of ways. A file of clipping, for instance, or a series of reports, notes, pamphlets and similar material, can be brought into logic and order by following the subject outline adopted in the classification system. Such material can also be filed under the new method of punch cards, enabling the librarian, metallurgist or researcher to assemble at a moment's notice the fullest possible background reference on any of scores of processes, properties or materials.

The new ASM-SLA system is particularly adapted to the coding and classifying of metal literature annotated in the monthly news digest, *Metals Review*, published by the American Society for Metals. Starting with the February 1950 issue of *Metals Review*, the annotations of metallurgical literature will be segregated under 19 main subject headings with symbols at the end of each abstract as reference guides to the system's operation.

The full scope of classification, however, covers all sources of metallurgical information, and provides ample opportunity for the specialist to expand its application to any desired degree.

New Hobart Distributor

Hobart Brothers Co., Troy, Ohio, named White Welding Supply Co., St. Louis, Mo., to represent it exclusively in the sale of Hobart Arc Welders, Electrodes and Accessories for metropolitan St. Louis and the surrounding Missouri and Illinois counties.

Shipbuilding Production in 1949

In his Annual Report to the American Bureau of Shipping, J. Lewis Luckenbach, retiring president who becomes chairman of the Board, gave a detailed analysis of the shipbuilding situation in the United States. We believe the following extracts will be of interest to our readers.

"Welding, in place of riveting, was developed in the United States to the point where the largest vessels are now practically all-welded, speeding up construction time by permitting the assembly of large sections, and reducing the total weight.

"The Bureau's requirements for Hull Steel which were adopted in 1947, as a result of the comprehensive investigations which had been carried on up to that time in connection with failures in the larger types of welded vessels, have now become universally accepted in the steel making industry in the United States. Since the adoption of these new requirements there have been completed and are now in operation 11 large oceangoing tankers using steel in accordance with these new Rules. In addition, there are 9 large ocean going tankers in operation which were under contract at the time of the adoption of the new specifications and for which it was possible to change the steel orders to the extent that the improved steel was used for the principal structural parts. All of the large oceangoing merchant vessels at present under construction in United States shipyards are being built with steel in accordance with the new specifications and many repair yard orders are being filled with this steel. Samples of the steel obtained from the material as actually being supplied to the shipyards have been tested in our Laboratory and these tests have indicated a very marked improvement in energy absorption values and transition temperatures over and above the values which were being obtained with steel produced in accordance with our previous specifications. Corresponding testing is being carried out by the Steel Makers themselves and such preliminary information as has been released substantiates our own results.

"As mentioned in the report last year, there has been a continuing trend in engineering design in new construction to the use of higher steam temperatures, 1020° F. for one group of ships, which necessitates more extensive use of alloy steels. During the past year the Staff has made an intensive study of the problems introduced by this development. This study disclosed that none of the recognized standards, such as the A.S.M.E. Boiler Code, A.S.M.E. Power Piping Code, the A.S.A. Standards for Valves and Fittings and the Welding Society Codes, covered installations for temperatures in this range and that while the Codes were in the process of revision it could not be expected that the revisions would be completed in time for application to the installations now in hand. Therefore, a number of the leading Metallurgists, Welding Experts and Engineers who have been associated with high temperature installations in both central power stations and the oil refineries were invited by the Bureau to serve as an Advisory Panel. As a result of this activity, the Bureau has issued, in mimeograph form, an Interim Guide for the Installation of High Temperature Steam Piping on Ships, which is presently being followed for the new construction."

G. E. Power Train

Welders at the Worcester, Mass. plant of the Pullman-Standard Car Mfg. Co. work on one of the nine stainless steel exhibit cars for the General Electric Apparatus Department's "More Power to America Special," Fig. 2. For these welding operations, G-E equipment is being used. The MPA Special, carrying dis-

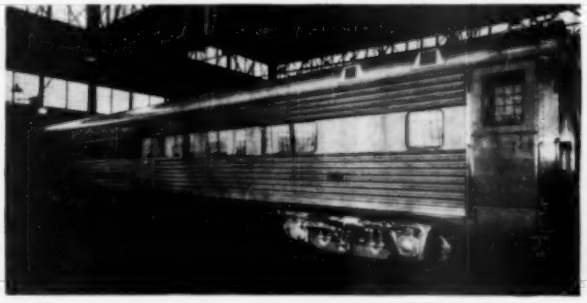


Fig. 1

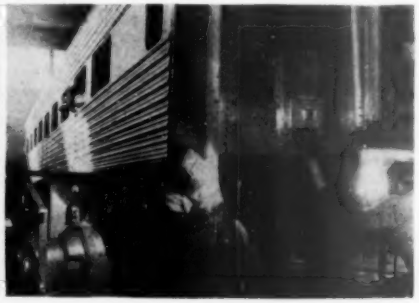


Fig. 2

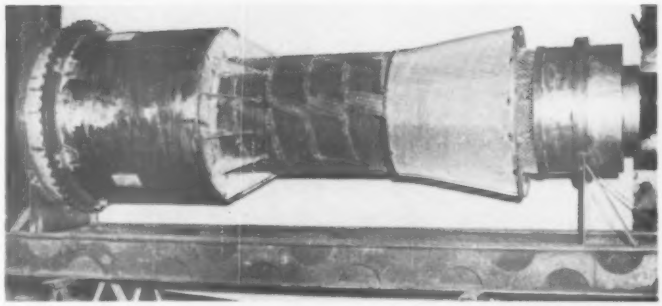
plays of more than 2000 of the latest electrical products and techniques, will begin a nationwide tour of key industrial centers this Spring.

One of the exhibit cars of the General Electric Apparatus Department's "More Power to America Special" nears completion in the Worcester, Mass. plant of the Pullman-Standard Car Manufacturing Company (Fig. 1).

The first train of its kind in industrial history, the MPA Special will exhibit a complete range of electrical apparatus, from precise aircraft instruments to complex operating system of steel mill, textile, and other industry equipment. It will be launched this Spring on a nationwide tour of key industrial centers for inspection by utility and industrial executives and municipal leaders.

Corroded Unit Replaced with 18-8

When the carbon steel washing and rinsing unit of a large tumbling machine corroded so rapidly that it set up a difficult problem of cleaning and maintenance, it was decided to have a replacement unit made of Type 304 stainless steel. Contract for the fabrication was awarded to Storts Welding Co., Meriden, Conn., who specialize in the manufacture of welded fabrications to order. The original unit was shipped to the Storts plant to facilitate the checking of dimensions. Dimensional accuracy was very important because this unit has to fit perfectly into a larger machine.



The first section of the unit (going from left to right) is a drum 38 1/2 in. long and 35 in. in diameter. This is made of 11 gage stainless sheet. The same material is used for the triangular gussets which hold the drum rigidly in alignment with the mesh cylinder. Welded to the inside surface of the drum is a worm 4 in. high made of 14 gage strip. The worm has a 7-in. pitch and coils around the inside of the drum four times. The worm continues all the way through to the discharge hopper at the right end of the unit, being the means of propelling the work material through the unit. At regular intervals formed pieces of 11 gage sheet in the shape of inverted V's are welded to the inside wall perpendicular to the worm to provide the tumbling action.

The second section is a 24-in. diameter cylinder of 3 1/2 mesh, 40 in. long. Next comes a 24-in. diameter cylinder of 2 mesh, 28 in. long. This mesh is coarse enough to allow the tumbling materials to drop through into the outside cone, which is 5 1/2 mesh, and be discharged into a hopper, while the workpieces are passed through the discharge hopper to the next operation.

Type 304 stainless steel was used throughout in the fabrication of this replacement unit, and it was all metallic arc welded. It was possible to salvage for reuse the original forged steel tires and the gears, which are shown in position at the ends of the unit. A critical factor in the fabrication was to preserve the alignment of the tires and gears, so that the unit would fit perfectly into the machine and operate smoothly and efficiently.

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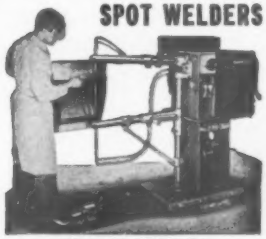

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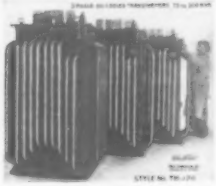

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New Radiography Technique Speeds Ship Sailing

When steam boilers or pressure carrying steam piping aboard a ship are repaired, replaced or modified by welding it is necessary to satisfy the responsible and governing inspectors as to the satisfactory nature of the welds made. They must be free of cracks, excessive holes or slag inclusions and must represent good fusion of the base metal. The customary method of inspection is that of gamma gay or Radium radiography.

Gamma ray radiography required a suitable source of the rays, such as Radium or other radioactive material methods for suspending this source in a proper position on one side but at some distance from the weld; suitable film in special cassettes with special intensifying screens; methods of holding these cassettes in position on the other side but close to the weld; suitable penetrameters to prove the sensitivity of the procedure; a calculated time for the exposure; suitable dark room facilities for loading and unloading cassettes and developing the film; and considerable know-how and experience.

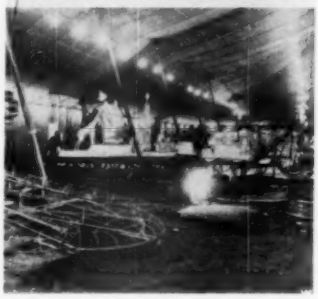
The entire procedure may take considerable time. An example was in a recent ship case where certain nozzle additions were made to the current boilers. Radium radiography of the welds by conventional methods required for each nozzle several hours for set-up time, some 14 hours of radium exposure and in addition several hours for processing of the film away from the ship.

Similar nozzle additions were required to be made to another ship. The ship was ready to sail, passengers awaiting embarkation were being housed at local hotels at the ship's expense, the crew was being paid, pier and other charges were mounting, every hour of delay meant many dollars. Sam Tour & Co., Inc. field personnel applying their new radiographic technique and field equipment reduced the time required for each nozzle for setting up to less than an hour and the radium exposure time to 2½ hr. By taking portable dark room film developing equipment aboard the ship the films were developed and viewed by the inspectors within 15 minutes after exposures were finished. The net result was the saving of several days of total time and a like advance of the sailing date of the ship.

The new techniques involved the making of a scale drawing to enable exact exposure calculations, the simultaneous use of two or more gamma ray sources, the use of heavy lead shields to stop cross radiation plus the use of portable dark room equipment.

California Welds Float

Floats for the famous Rose Parade before the Rose Bowl football game in Pasadena, Calif. have more and more in recent years been made with welded steel construction to reduce the cost of assembling these floats which, for the most part, are used only once then discarded.



The old method of constructing the large figures of solid plaster was time-consuming and required skilled help. Now by the use of welding, a frame for figures is built up of lightweight angle iron and ¼-in. rod stock hand bent to the desired shape. The outline of the figure thus formed is then covered with wire netting to which is applied cheesecloth that has been dipped in plaster of paris. Compared to modeling in solid plaster, the application of cheesecloth to this framework is a relatively simple job that is done in a fraction of the time previously required.

A large circus tent provides a protected area where floats are constructed and decorated. Flowers, decorating the floats, are kept fresh by inserting their stems into water filled test tubes that are wired to the netting and cheesecloth. Welding on the floats was done this year by Kenny's Welding Service of San Gabriel, Calif. Photo and data courtesy Lincoln Electric Co., Cleveland, Ohio.

Chicago Fair of 1950

"Frontiers of Freedom," a new historical pageant of Hollywood magnitude expected to dwarf in pulling power the eminently successful "Wheels A-Rolling" production staged here during the past two summers, will be one of the headline features of the Chicago Fair of 1950.

The Chicago Fair of 1950 will open June 24 and continue through Labor Day. Major exhibitors will be representative of the nation's largest industrial and commercial concerns.

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Until recently, piping engineers were limited in their choice of piping materials to carbon steels, a few low alloy steels, wrought iron, cast iron and brass.

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Rapid corrosion of piping by the fluid handled, or contamination of the fluid by corrosion of the pipe—or by catalytic action of the pipe material with the fluid, are problems which today's piping engineer faces. Often, these problems are complicated by pressures and temperatures at which the fluid must be conveyed, or by wide fluctuations of pressures and temperatures when the process is cyclic in nature.

Each of these service conditions demands utmost care in the selection of the piping material.

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NEW PRODUCTS

Electric Control Operated by Water Flow

A new control device which responds to a flow of cold water to open or close an electrical contact has been announced by General Electric's Control Divisions.

Called a flow interlock, the device measures approximately $2^1/_2$ x 3 x 7 in. In operation it closes a contact when a flow of water exceeds a preset amount and opens it when the flow falls below the preset amount. Working under this principle, the device actually acts as a fuse in a circuit which depends upon water cooling for protection.

According to G-E engineers, the interlock can be used as a safety device in many other applications where it is desirable to actuate an electrical contact with a flow of water. It can be used in hot water heaters, welding units, kitchen waste units, transformer cooling, induction heating, television luminaires, water-cooled dynamometers, etc., they said.

Adjustment can be made to control the circuit for any flow from one to four gal. per minute. The flow differential between the cut-in and the cut-out of the electrical contact is 0.2 gal. minimum and 0.4 gal. maximum. The interlock does not control the amount of water flow, but this can be accomplished, it was said, by installing throttling or regulating valve ahead of the device.

The interlock mechanism is available complete with union fitting and strainer attachment. The strainer keeps foreign matter out of the housing.

Designed to operate for the amount of flow independent of pressure, the interlock is intended only for cold-water applications. For use with other fluids it is recommended that the manufacturer be contacted for more information.

Electrical rating of the device is 10 amp. at 125 v., 5 amp. at 250 v. and 3 amp. at 460 v., all a. c. Maximum line pressure that the flow interlock will withstand is 125 psi.

Contour Marker

The Contour Marker Corporation of California, 1843 E. Compton Blvd., Compton, Calif., takes great pleasure in announcing the new Jumbo Contour Marker. This Contour Marker has the same careful engineering and construction as the standard model. Will work any size pipe from 16 to 48 in. Complete with adapter for square or rectangular shapes, and equipped with belt to fasten on pipe. Packed in wooden box.

Pipe Scalloper

The Stratford Pipe Scalloper will cut, contour and chamfer in one operation any steel pipe from 1 to 12 in., and from 6 in. long to any desired length. In addition to shaped nipples, it will make square or oblique cuts including chamfer. Further information may be obtained from Harold Dessau, 25 Murray St., New York 7, N. Y.

60% by Weight Neoprene Jacket

Welding cables with jackets certified to contain not less than 60% by weight of new Neoprene are being introduced this month by Western Insulated Wire Co. of Los Angeles.

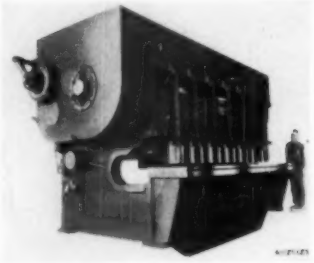
The superiority of Neoprene over rubber as a jacket compound—its longer-aging characteristics, its greater resistance to oil, ultraviolet, ozone, abrasion, heat, cold and flame—is multiplied by the additional Neoprene found in the Bronco 60 *Certified* jacket.

Bronco 60 Certified Welding Cable is made in standard sizes, 8 to 4/0.

Largest Steelweld Shear

The largest Steelweld Shear built to date has just been completed by The Cleveland Crane & Engineering Co. Wickliffe, Ohio.

The machine has a shearing capacity of 12 ft. of 1-in. steel plate. Although this is the heaviest Steelweld Shear, it is not the longest, for Steelwelds have been built for cutting plate up to 18 ft.



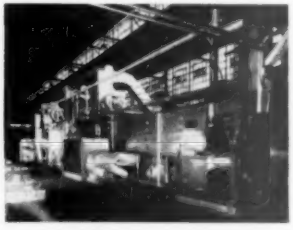
The machine has no slides or guides for the knife to work in, because it makes use of a pivoted-blade cutting principle which is exclusive with Steelweld Shears. The upper blade operates on two heavy pins secured to the side frames and travels in a circular path.

An outstanding feature is the exclusive Micro-Speed knife adjustment which makes it extremely easy and fast to change knife clearance to suit various thickness plate and thereby enable making the best possible cuts. This is done in a matter of seconds by simply turning a convenient hand crank and watching a dial indicator that shows the clearance in thousandths of an inch, and also the plate thickness that may be cut for any knife setting.

This shear cuts at the rate of 25 strokes per minute. The throat is 24 in. deep which is standard for all Steelwelds. Both frame and blade are of all-welded one-piece steel construction. The frame bed and crown are welded integral with side frames to assure permanency and provide rigidity and life-time accuracy. The bed has ball bearing transfers to facilitate the movement of steel through the knives.

600-Ft. Long Electrode Drying Ovens

A new type high-temperature oven, designed especially for continuous drying and conditioning of extrusion coated low hydrogen and stainless-steel welding electrodes, has recently been placed in service at the P & H Electrode Plant in Milwaukee. This modern oven, the largest of its kind, contains 600 lineal feet of processing space and has six separate temperature zones and a possible temperature variation from room up to 1000° F. Each zone is equipped with separate humidity, temperature and speed controls. Processing time can be varied from 20 to 120 min. for the precise requirements of the various types of P & H Electrodes. The oven will handle all popular sizes of commercial electrodes.



Another addition at the P & H Electrode Plant is a new extrusion press equipped with latest developments, and built to take care of the full capacity of the new drying oven.

Completing this phase of the P & H program for scientific manufacture and accurate control of electrode quality is a new kind of moistureproof packaging which assures factory fresh electrodes at all times.

Self-Pressure Torch

A new, half pint, self-pressure torch—complete with many big torch features—is being introduced by Turner Brass Works, Sycamore, Ill.

Designated as the No. 59 for gasoline and No. 60 alcohol, the torch is genuinely practical for a wide variety of indoor home uses, light shop work or hobbycraft work. Chief among its outstanding features is the fact that it is complete with soldering iron rest and windshield.

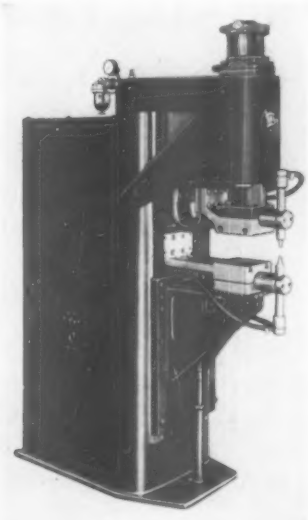
The high-polished, heavy gage brass tank of this new model is $3\frac{1}{2}$ in. in diameter—a feature which minimizes tipping. The tank holds $7\frac{1}{2}$ oz. of fuel and the torch will burn $3\frac{1}{2}$ hr. full open at a temperature of 1700° by pyrometer reading.

This torch does not require a pump as a brass wire, interwoven with the wick, it conducts heat from burner into the tank.

Projection Welders

A new line of Press Type, Air-Operated Projection and Spot Welders has just been placed in production by the Banner Mfg. Co., of Milwaukee, Wis.

Many innovations in design and construction have been incorporated to provide fast action, more accurate work and longer service life. They are built in sizes ranging from 50 to 150 kva.

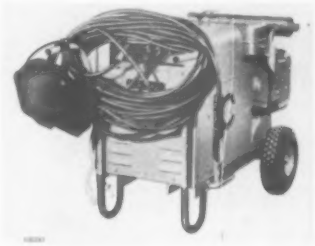


The Roller Head is air operated and specially designed to assure fast, accurate performance. The quill is guided by 8 rollers, mounted on the gib, which assures rigidity and positive alignment regardless of stroke length. The mounting of the rollers reduces friction losses and any possibility of deflection.

The entire unit is built for heavy-duty service, with a $\frac{3}{4}$-in. boiler plate front, heavily braced and ribbed to withstand severe service. For additional information, write Banner Mfg. Co., 4934 N. 29th St., Milwaukee, Wis.

Versatile Welder

The Miller Electric Mfg. Co., of Appleton, Wisconsin, has announced a new, engine driven, combination a.-c. arc welder and 3-kw. power plant. This new unit is available either as a stationary model designated Model AEA-200-L or a completely portable unit on a rubber-tired truck, the Model AEA-200-L-P. Both are ideal for welding, pipe thawing or as 3-kw. power plants.



For welding, the unit will handle all a.-c. or a.-c., d.-c. electrodes from $\frac{1}{16}$ to $\frac{5}{16}$ in. inclusive. It will deliver a full 200 amp. of welding current.

For pipe thawing, the high cycle a.-c. current will thaw pipes much faster than d.-c. current at a much lower current setting. This a.-c. generator is built for the high-duty cycle of operation required in pipe thawing. The warranty fully covers pipe thawing of iron pipe.

For power, the machine provides 3 kw., 110/220 v. a.-c., 60 cycle single-phase current. A conveniently located switch enables the operator to change from welding generator to a power plant to operate lights, motors and electric tools when no power lines are available. Also, if the normal power supply should fail, this is an ideal unit to use as emergency power to operate lights and appliances (electric stove, deep freeze unit, electric milker, electric pump, etc.). The unit connects directly to the normal power service.

The generator is powered by the Onan 2-cylinder, 4-cycle air-cooled engine and is light in weight. It is a rotating field type machine, the same type as the big alternators that generate power for towns and cities where proved dependability is essential.

Illustrated literature describing and pricing these models is available through your nearest Miller distributor or by writing directly to the factory.

CUT WELDING COSTS 26.3%* with

Norelco CONTACT WELDING ELECTRODES

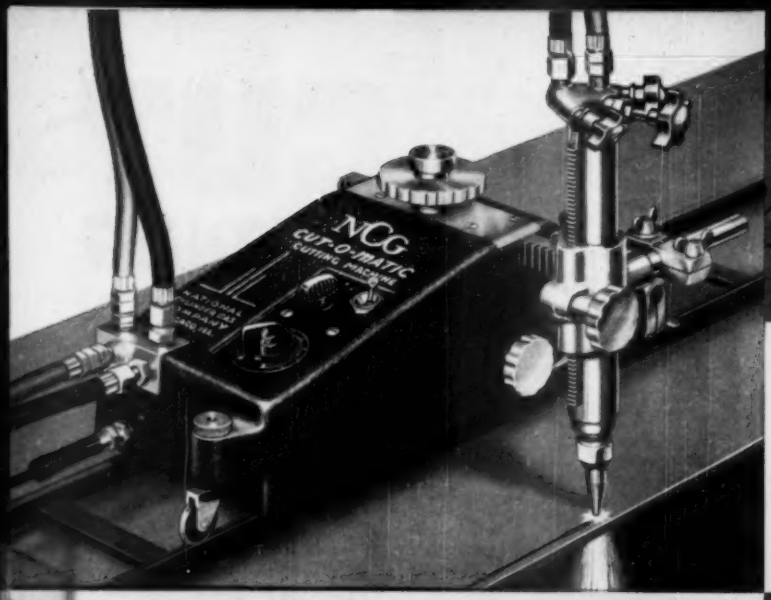
• With this entirely *new type* of rod, welding speeds are increased an average of 45%. Welding is made much easier by touch-welding in all positions; and quality uniformly improved through less distortion, undercutting, and better control.

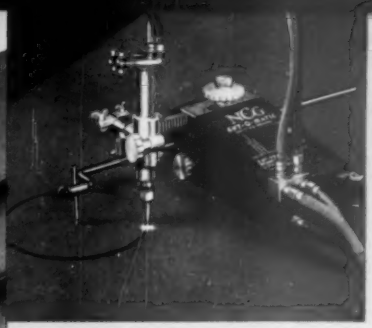
Available in two types: Contact 18 (in conformance with AWS E6013 class) for fast all-position general-purpose welding, and Contact 20 (AWS 6020 class) for extremely fast production welding in horizontal and downhand positions. Both AC or DC.

Norelco CONTACT WELDING ELECTRODES

*For full details of actual production results, technical information and prices write:

NORTH AMERICAN PHILIPS COMPANY, INC.
100 East 42nd Street, Dept. WD-4,
New York 17, N.Y.





CIRCLES AND ARCS

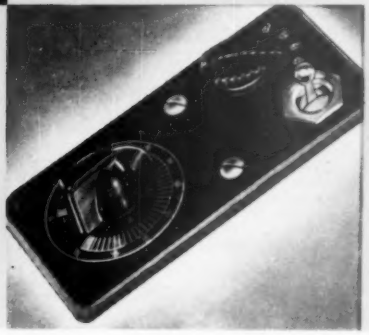
Circles or arcs, up to 60-in. in diameter, are cut by attaching radius rod assembly. Larger diameters may be cut with extension rod. Rings may be cut with double torch mounting.

SIMPLE CONTROLS

The Cut-O-Matic Control Panel is simple. A selector switch sets the travel at one of four speeds, and a rheostat permits accurate regulation anywhere between 4-in. and 60-in. per minute, in either direction.

CUT-O-MATIC

NCG'S PORTABLE, MOTOR-DRIVEN FLAME-CUTTING MACHINE



LOW-COST, VERSATILE, ACCURATE, FAST

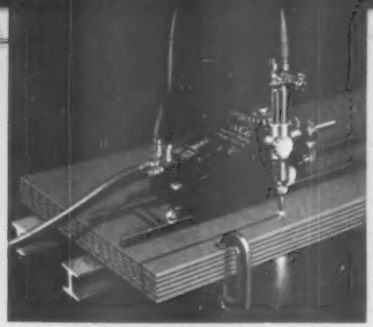
Flame-Cutting with Substantial Savings in Labor and Materials

Here's a small, inexpensive cutting machine that's so efficient that grinding or machining of cuts are rarely necessary . . . That's so versatile you can cut light plate or heavy slabs—straight lines, bevels or various shapes . . . That's so portable you can take the machine to the job—inside or outside the shop, wherever power is available. And it has exclusive operating features that make it remarkably easy to handle.

Yes, the NCG Cut-O-Matic is so efficient and so flexible in use that one man and a Cut-O-Matic make a hard-to-beat team to save time, labor, and materials.

The Cut-O-Matic is not only a money saver in the larger plant but in small shops, too. In countless instances the low price of the Cut-O-Matic has enabled small businesses to enjoy the recognized superiority of machine cutting—with its sharper, cleaner cuts and its overall economies in time, materials and gas.

Cut-O-Matic offers so many advantages that you'll want a copy of the illustrated booklet describing the unit in detail. If you'd like a demonstration right in your own shop, just check the box in the coupon at the right.



STACK CUTTING

Stack cutting gives real production economy and speed. Sheets clamped together may be cut uniformly. Circles and arcs as well as straight lines are easily stack-cut.

STRIP CUTTING

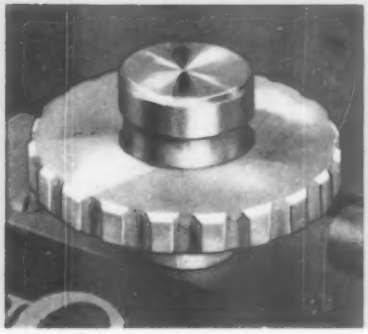
Strips up to 29-in. wide can be cut by adding torch holder, torch and hose assembly. Wider strips may be cut by using extra length equipment. Narrow strips may be cut by mounting two torches side by side.

IRREGULAR SHAPES

Limited irregular shapes may be cut by guiding the Cut-O-Matic by hand. Rear wheel is castered to facilitate travel. Cuts are much better than those made with a hand cutting torch.

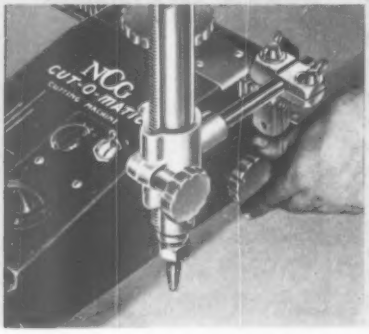
FREE-WHEELING

Fingertip clutch control is combined with a cross-feed gear rack adjustment to permit moving the machine on track while adjusting the cross-feed, in one simultaneous operation.



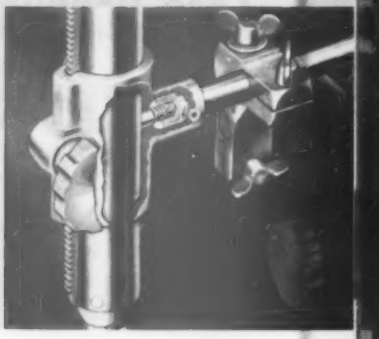
EASY CHANGE-OVER

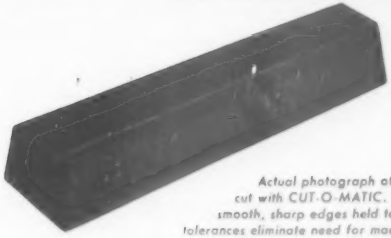
It's easy to switch from cutting straight-line to circles. The friction knob is loosened, as illustrated, and the inside drive wheel is disengaged. The outside wheel then propels the machine around the center point.



SMOOTH—RIGID

No ragged cuts caused by excessive play and uneven racking. A special clamp adjustment, plus a spring-loaded pressure plug, holds torch in rigidly, yet permits smooth racking.





Actual photograph of bevel cut with CUT-O-MATIC. Clean, smooth, sharp edges held to close tolerances eliminate need for machining or grinding.

NCG CUT-O-MATIC STANDARD UNIT

F.O.B. FACTORY, LOUISVILLE, KY.

$185

Complete with torch, tip, radius rod, track, hose, cable and torch wrench.

CUT-O-MATIC possesses all the quality characteristics of famous NCG heavy-duty flame-cutting equipment. Sturdy, simply designed for efficient operation and easy maintenance, the CUT-O-MATIC is a dependable tool that will give you long trouble-free service.

NATIONAL CYLINDER GAS COMPANY

NCG

EVERYTHING FOR WELDING

Executive Offices:

840 N. Michigan Avenue, Chicago 11, Illinois

Copr. 1950, National Cylinder Gas Co.

NATIONAL CYLINDER GAS COMPANY
840 N. Michigan Ave., Chicago 11, Ill.

Please send me Illustrated Booklet N-134 describing in detail the versatile CUT-O-MATIC Flame-Cutting Machine.

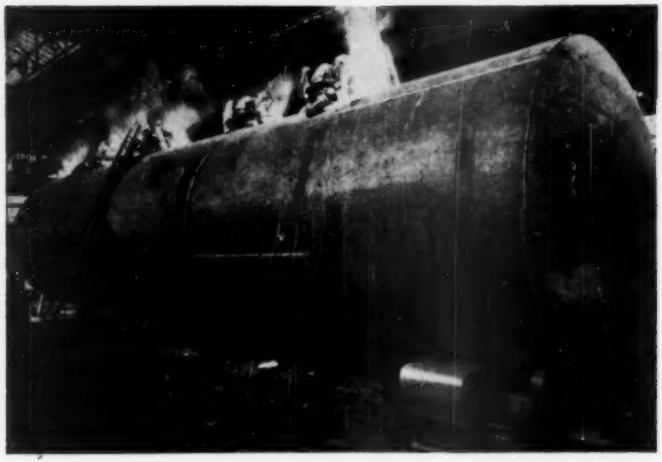
NAME_____ POSITION_____

COMPANY_____

STREET ADDRESS_____

CITY_____ ZONE____ STATE_____

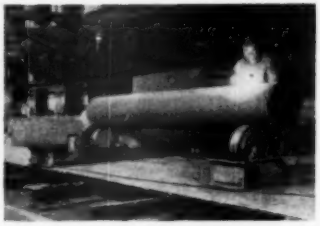
☐ I would like a demonstration in my own shop.



Less Handling—More Welding

It's handling that costs most in welding . . . the crane work or manual labor in positioning the pieces—plus the welder's *waiting* time.

Get more arc-time from every hour by using Worthington-Ransome Turning Rolls to handle tanks, drums or any type of cylindrical vessel regardless of size. They continually bring the work into position for efficient, economical *downhand* welding (manual or automatic) with heavier electrodes which means fewer passes and better welds.



50% greater production on both repetitive and job work has been reported by users.

Capacities from 3 to 75 tons, up to 14 ft. diam., stationary or self-propelled. (Rolls for heavier or larger work also available.)

WORTHINGTON

WORTHINGTON PUMP AND MACHINERY CORPORATION

Welding and Assembly Positioning Equipment Division

DUNELLEN, NEW JERSEY

Y9.7

Worthington Pump and Machinery Corp.
Dunellen, N. J.

Please send Bulletin 228 on Worthington-Ransome Turning Rolls.

NAME.....

COMPANY.....

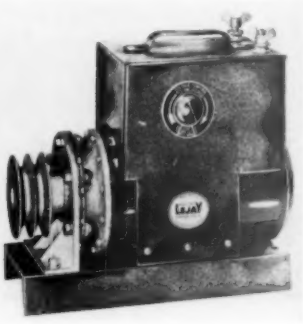
ADDRESS.....

Portable Arc Welder

Now when Farmer Brown's cultivator or harrow breaks down far afield, no longer does he have to lose half a day going into town to get heavy welding equipment. He just hitches a handy "on-the-job" LeJay portable Arc Welder to his tractor or wagon—takes it out to the crippled machine—and does the job himself, quickly and easily!

The new LeJay Arc Welder operates on the powerful Bendix P-2 generator, the same as used in large turbo-jet and bomber planes. Light in weight, the welder does any and all jobs, whether light or heavy, in the 200–300-amp. range.

The versatile LeJay Arc Welder is easily mounted on any jeep, trailer or tractor—it can be bolted down for engine or motor drive, if desired. With this model it is easy for one who has never welded before to do all his own work without too much difficulty, as many farmers will readily testify. The welder is not to be confused with "light" welders. This is a heavy duty machine which can handle heavy work such as frames.



The LeJay delivers 200 amp. continuous duty, up to 300 amp. intermittent duty. Welding range is by dial type control.

It may be purchased direct from the LeJay Mfg. Co., Minneapolis 8, Minn.

Leak Detector

McHale Mfg. Co., of Los Angeles, fabricators of dairy equipment, have installed General Electric Type H Leak Detectors for detecting leakage in their stainless steel milk storage equipment.

Modern Dairy procedure dictates the use of large, sanitary, refrigerated storage facilities to maintain milk fresh and pure until ready for processing. Farmers and creamery operators are faced with the problem of sanitary milk storage, up to 15,000 gallons capacity. The refrigerating tanks must be tested to make certain that all welds are air tight so that one refrigerant does not escape. If a leakage occurred while in use the entire contents of the tank would be spoiled.

The testing process was formerly done by means of a bulky hydraulic pressure system. It is now accomplished rapidly and with greater accuracy by means of a portable leak detector.

Your Children Are America's Future!

The American Family is your biggest stake in the future. The ideals . . . the morals . . . the spiritual values we teach our children *now* will be the strength of our nation tomorrow. And nowhere are the seeds of true democratic citizenship more firmly planted than in our nation's Sunday Schools.

April 10th to 16th, 1950, is National Sunday School Week. Won't you add your support to the growing number of industrial, labor, and civic leaders who endorse it?

This advertisement is published in the interest of The Laymen's National Committee, by Rene D. Wasserman, President, Eutectic Welding Alloys Corporation, 40 Worth Street, N. Y. C.

NATIONAL SUNDAY SCHOOL WEEK
is sponsored by:
The Laymen's National Committee
4 Park Avenue, New York 16, N. Y.
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Precision Regulation
for
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ACETYLENE
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The precision performance of the two-stage RegOlator is especially desirable for piped distribution systems and other applications where large volumes of high pressure gases must be controlled accurately.

Two-Stage RegOlator Gives You Plus Performance!

Constant delivery pressure regardless of drop in pressure at the inlet... Patented design incorporates nozzle-type first stage counterbalanced by stem-type second stage... Triple action cartridge filter eliminates troubles usually caused by rust, dust or dirt.

Listed by Underwriters' Laboratories, Inc. and Factory Mutual.

Write for complete information.

*Reg. U. S. Pat. Off.

The BASTIAN-BLESSING Company
4201 West Peterson Ave. Chicago 30, Illinois

PIONEER AND LEADER IN THE DESIGN AND MANUFACTURE OF PRECISION EQUIPMENT FOR USING AND CONTROLLING HIGH PRESSURE GASES

By introducing a small amount of carbon tetrachloride into the refrigerating system, leaks can be quickly and easily located. The barrel of a hand-held "gun" is passed along the weld. When a leak is detected an indication on a control unit to which the gun is connected shows instantly that the weld is leaky.

The control unit operates from 115 v. a.c., 60 cycles. It is light and compact enough to be carried by an attached handle or may be slung on the shoulder with a strap. Headphones can be used in conjunction with the unit to give an audible indication of a leak.

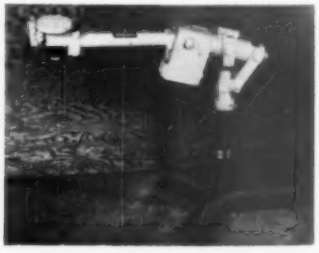
This instrument can detect a leak so small that in one year only 1/100 of an ounce of carbon tetrachloride will pass through the opening.

Improved Positioner

Aronson Machine Co., has brought out a new positioner to allow a maximum capacity of 1000 lb. This model is designated the 14C1000 Universal Balanced Positioner.

Another design change is on the two rotations. The work table and work arm now have brake bands for friction. The brake bands are actuated by a knob that is turned in drawing the band around the rotation. The purpose of this feature is that the workpiece can readily be held during grinding, polishing and assembly operations without the workpiece moving.

The worm adjusting control has been moved to the bottom side to allow large diameter workpieces to rotate clear of the old obstruction.



Tube Welding Attachment and Spot Welder Unit

Electrical Maintenance & Engineering Co., 12525 Euclid Ave., Cleveland 12, Ohio has recently developed a tube welding attachment that is supplied with a spot welder. This complete unit can lap weld very thin wall tubes of 0.010 to 0.025 wall thickness. The tube length up to 31 in. is placed in curled form onto a mandrel that moves with the tube, the tube first passing through a guide that properly laps the two edges and locates the lap for welding, the tube then going through a sizing funnel that draws the diameter down to the proper diameter, then the tube passes under the welding wheel that with proper control can lay a straight line of equally spaced spots, with short stretches of continuous weld for the purpose of beading if required, after which the tube emerges through a no-back stripper that takes off the tube without

the aid of an operator, as the mandrel automatically returns to its original position. Upon the return stroke of this reciprocating mandrel the operator presses the next curled tube on, that again goes through the welding operations. This continuous method of welding, by using a reciprocating mandrel, allows very accurate control of the diameter of these thin wall tubes, and with one operator only required to put the tubes on allows maximum production. The capacity of the spot welder ranges from 20 kva. up depending upon the type of weld and gage of metal in the tube. The welder is altered to give the proper voltage characteristics required, but can be restored to its original rating later if desired. A production rate of 4 to 10 tubes a minute is possible depending upon the gage of metal and the length of the tube.

New Forming Method

Tool Research Engineers who developed Marform at the Glenn L. Martin Co., Baltimore 3, state formed sheet-metal parts now can be produced at savings as high as 50%. They estimate that the new method can produce savings of hundreds of thousands of dollars annually for the

GET OFF TO A

FAST START!

FOR THE BEST RESULTS AT LOWEST COST

IN WELDING

IN CUTTING

IN SAFETY EQUIPMENT

BEST BUY BURDOX

* Time lost in preparation, in looking for tools, in makeshift arrangements costs you money! You can't expect your men to do good work without good tools and accessories. Get the best in welding, cutting and safety equipment without paying premium prices by specifying BURDOX. Typical of the outstanding value and high quality of the entire BURDOX line are the products shown below. Made by welding men for welding men they reduce lost time, improve performance. Write for free catalog today and start saving with BURDOX at once!

CYLINDER TRUCKS DELUXE MODEL— The greatest cylinder truck value you've ever seen! Streamlined one-piece safety handle. Streamlined tool tray and rack. Bicycle type wheels with solid rubber tires. All welded construction. Chain holds cylinders securely.

JUNIOR MODEL—Ideal for handling small size cylinder! All welded tubular construction, mechanical rubber tires, oilless bronze bearings. Rolls like a charm. Adjustable telescoping tubular device holds cylinders securely.

CYLINDER CONNECTIONS— All brass, made to close tolerances. Guaranteed against mechanical defects. Finest made, yet cost no more.

EYEGARD HELMETS—Made to give the welder extra comfort, extra protection. Exclusive adjustable type headgear for "featherweight" fit.

EXTRA-FLEX CABLE— Extra-flexible, extra-resistance to abrasion, oil and water because of special construction. Millions of feet sold because of performance and price.

TRIP-L-ITE FLINT LIGHTERS— Lasts three times as long as ordinary lighters. Produces a hot, fat spark every time. Works easy, insures instantaneous lighting.

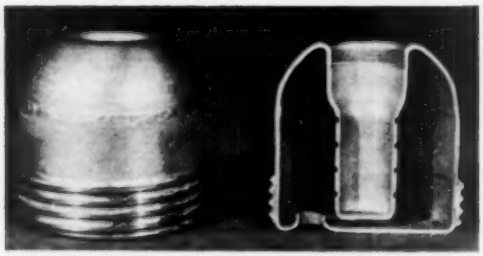
THE BURDOX LINE INCLUDES:

WELDING AND CUTTING EQUIPMENT AND MACHINES • SOLDERING AND BRAZING OUTFITS • INDUSTRIAL GASES • REGULATORS AND GAUGES • HOSE AND CABLE • ACETYLENE GENERATORS • GOGGLES AND HELMETS • LENSES AND FACE SHIELDS • ROD AND FLUXES • CLYINDER TRUCKS

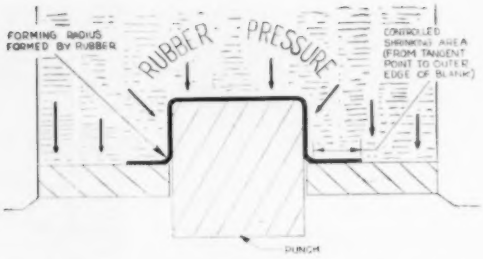
THE BURDETT OXYGEN COMPANY

GENERAL ELECTRIC

Arc-welding Distributor



Cutaway view of the upper half of an igniter head



Sketch illustrates the Marform punch and the Marform plate on which the yet unformed metal rests

aircraft industry. Farther afield, in production for the multitude of other industries requiring metal forming, they estimate that the new process can effect economies which would mount into the millions.

It is revealed that the new method results in a substantial increase in the rate of production of numerous types of detailed parts, and a considerable decrease in labor and tooling costs.

Using Marform, it is possible to form certain stainless steel exhaust stacks, for example, with greatly diminished tooling expenditures and at a manufacturing rate increased over conventional methods. In addition, it is very important that as uniform a cross-sectional thickness be maintained as possible to attain the required strength and to increase the service life. A variation greater than 5% in material thickness is unusual in severely formed parts made by the Marform process.

Some Technical Aspects of the Marform Process

The principal feature responsible for the success of the Marform process is the precision control of the pressure curve for the forming cycle of the part. This control of the pressure enables a part to be formed free of wrinkles and reduces springback to a minimum.

The operator can make complex sheet-metal parts involving drawing, shrinking and stretching at the rate of 50 to 120 per hour. Higher press speeds and multiple tooling will increase this rate proportionately.

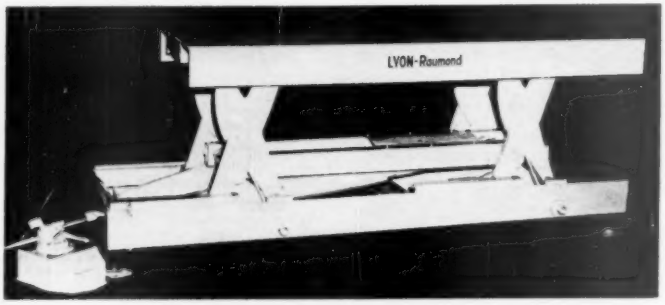
Compound Lever Hydraulic Elevating Table

An exceptionally low height and a greater range of elevation is made possible with the compound lever arrangement in a hydraulic sheet feeding table offered by LYON-Raymond Corp.

A standard model No. 1196 is available with a capacity of 10,000 lb. The range of elevation is from 12 to 36 in. thus providing a total lift of 24 in.

The platform is 36 in. wide by 96 in. long. End and side extensions are available to increase the platform area.

The new table also features a vertical



lifting arrangement and the manufacturer stresses the point that there are no uprights extending above the platform to stand in the way of overhanging material.

While offered with a two speed foot pump, a power operated pump with either push button or foot switch control is recommended for faster elevation.

The table can be furnished with wheels and casters to make a portable unit with a lowered height of 20 in.

Write to LYON-Raymond Corp., 23667 Madison St., Greene, N. Y. for literature on this and other standard models.

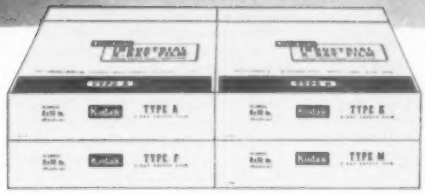
New Rotary Work Aligner

Johnson Machine Works, Eau Claire, Wis., announces production of a new Rotary Work Aligner for handling all types of materials requiring rotation in manufacture, assembly, welding or repair.

Money, time and trouble saving features of the new tool are that it insures perfect alignment of two or more pieces of work, eliminates expensive setups for miscellaneous jobs, is adapted to either centered or uncentered work and checks alignment or run-out of any circular material from 1/4

WHAT'S THE RIGHT X-RAY FILM?

ANSWER:



KODAK INDUSTRIAL X-RAY FILM, TYPE A

● To examine such a dense and thick material the radiographer takes advantage of Kodak Industrial X-ray Film, Type A. For, in order to keep exposure reasonably short, the high speed of this film is essential. At the same time, its high contrast and fine graininess enable him to take full advantage of the ability of the 1000 kv machine to detect weld irregularities.

A TYPE OF FILM FOR EVERY PROBLEM

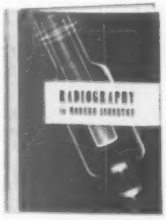
To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film. They provide the means to check welds efficiently and thus extend the use of the welding process.

Type A—has high contrast with time-saving speed for study of light alloys at low voltage and for examining heavy parts at 1000 kv. Used direct or with lead-foil screens.

Type M—provides maximum radiographic sensitivity, under direct exposure or with lead-foil screens. It has extra-fine grain and, though speed is less than in Type A, it is adequate for light alloys at average kilovoltage and for much million-volt work.

Type F—provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead screens.

Type K—has medium contrast with high speed. Designed for gamma ray and x-ray work where highest possible speed is needed at available kilovoltage without use of calcium tungstate screens.



RADIOGRAPHY IN MODERN INDUSTRY

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Radiography

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to 24 in. diameter. There are no limits to the length of material that can be worked as two or more Johnson Rotary Work Aligners may be used in handling long sections.

The new Johnson Rotary Work Aligner is a precision tool of finest quality material and workmanship. Its operation is simple and easy. The tool is designed and built with a ruggedness to withstand the severest use over a long period of time. At present four models are being produced in bed lengths from 5 ft. 10 in. to 11 ft. 6 in. with a load capacity of 1500 lb.

The new tool is extremely valuable to machine shops for checking alignment or run-out on any circular work either centered or uncentered. By using the tool, welders can easily rotate the work to produce uniform welds on tubing, shafting and other material.

For complete description and prices write, Sales Dept., Johnson Machine Works, 619 Menomonie St., Eau Claire, Wis.

SECTION ACTIVITIES

prepared by C. M. O'Leary

Anthony Wayne

The February meeting of the Anthony Wayne Section was held on Friday the 17th. The meeting was a plant tour of the Fort Wayne International Harvester Co. Preceding the plant tour a dinner was held in the Chamber of Commerce Building with an attendance of 88.

Following the dinner, everyone proceeded to the International Harvester Co. administration building where 11 more joined the 88 making a total of 99 that went on the plant tour. The gathering first had the pleasure of seeing the International Harvester Co.'s new color sound movie entitled "New Champions of Transportation." I. H. Company furnished a guide for every 10 men and a 3-hour tour of the main departments then followed. Generally, those participating seemed to enjoy the forge shop, truck assembly line, axle line and paint lines more than any others.

This was, without a doubt, the most highly successful meeting of the season.

Birmingham

The February meeting of the Birmingham Section was held on the 9th in the Redmont Hotel. Fifty members and guests heard Edward H. Roper, Assistant Manager of the Technical Sales Division, Air Reduction Sales Co., New York, give an interesting talk on "The Aircomatic Welding Process."

A lively discussion followed the talk and the Section was fortunate to have a speaker of Mr. Roper's experience to answer the many questions from the audience.

Boston

The regular monthly meeting of the Boston Section was held on February 13th at M.I.T., Cambridge, Mass. Instead of a coffee talk after dinner a colored moving picture entitled "Snow Train" was shown through the courtesy of the Boston and Maine Railroad.

The subject of the meeting was The New Steam Generating Unit at the Edgar Station of the Boston Edison Co. The first speaker George A. Orook, Jr., Asst. Supt. of Engineering, Boston Edison Co., gave an interesting talk about the size and the problems met in the design of the Station. The meeting was then carried on by speakers representing Combustion Engineering-Superheater, Inc. R. E. Lorentz, their Welding Metallurgist, talked about the design of the Drums and high-pressure steam lines, and J. H. Hunt, Welding Technician, told how the field welding was successfully done under very difficult conditions and some of the major welding problems, which was all very interesting. The Section had the pleasure of welcoming two visitors from Holland. A film showing the structural details of boiler drums, piping, etc. was shown.

Chattanooga

The following are the programs of Dinner Meetings held by the Chattanooga Section starting with the new season. All meetings proved very successful.

Nov. 4, 1949: L. N. Wall and A. R. McLain of Combustion Engineering-Superheater, Inc. gave a short discussion of their trip to the Metals Show in Cleveland, Ohio in October. Speaker at the technical session was Tom Ledbetter, Southern Sales Manager for the Ladish Co. of Cudahy, Wis., who spoke on "The Manufacture of Welding Fittings."

Jan. 6, 1950: "A.-C. vs. D.-C. Welding," by R. C. Freeman, General Electric Co.

Feb. 3, 1950: Forum on Boiler Installations and Repairs in Conjunction with the New State Law. Speakers—Lynn C. Peal, Acting Chief Boiler Inspector, State of Tenn., and W. G. McGlothlin, Brock and Blevins Co.

Feb. 8, 1950: Special meeting held at Combustion Engineering-Superheater, Inc Educational Dept. E. H. Roper, Assistant Manager of the Technical Sales Dept. of Air Reduction Sales Co., spoke on "The Aircomatic Process."

March 3, 1950: "Welding Metallurgy" by Prof. Herbert Kuenzel, Head of Department of Mechanical Engineering, University of Alabama.

Cleveland

Harold Jones of the Air Reduction Sales Co., presented a paper on "Newer Aspects on Developments on Gas Cutting and Welding" at the regular monthly meeting held on March 8th.

This interesting talk on new techniques in cutting was of considerable practical interest and value.

Departing from the industrial scene, Cleveland members heard Russell C. Huston give a short talk entitled "Ruminating on Ruminants," which was the story of his experiences running Congresswoman Francis Bolton's nearby Franchester Farms.

Colorado

February 14th meeting held at Silver Wing Inn, Denver, Colo. Clarence R. Steele, VP & GM, Silver Engineering Works, Denver, gave an excellent dinner talk on industrial impressions received on his recent trip to Europe.

Technical speaker was A. B. Tesmen, Development Engineer, North American Philips Co., Inc., whose subject was "Contact Electrodes in Application of Contact Welding."

Columbus

Frank E. Kessler, Sales Engineer, Welding Equipment & Supply Co., Detroit, Mich., was the speaker at the February 10th meeting held at Fort Hayes Hotel. An attendance of 78 were present at dinner and 98 at the technical meeting. This was a joint meeting with the American Society of Tool Engineers.

Mr. Kessler gave a brief summary of the history of Tool and Die Welding. Before the war his company was experimenting with this phase of welding and had met with some success. The war began and many companies looked around for some way to save their tools and dies when

engineering changes or repairs were necessary. First, electrodes had to be developed to weld the four basic types, air hardening, water hardening, oil hardening and hot working tool steels. Then welders had to be trained in their use. A real saving in production and cost was accomplished during the war in this industry. Procedure in welding dies is very important. Mr. Kessler explained the time and cost consumed in making a new die was often lost by not using the proper welding procedure in repairing them.

Detroit

Annual "Quiz the Experts" program was held on February 10th at the Engineering Society of Detroit, with an attendance of 145. Detroit came out on top with most points over the Niagara, Indiana and Anthony Wayne Sections. The competing teams, were as follows:

Anthony Wayne Section: B. G. Bishop, George H. Laws, Harry M. Johnson and Max L. Clark.

Niagara Frontier Section: Charles H. Jennings, C. E. Jackson, R. Thomas Breymeyr and C. B. Stadum.

Indiana Section: E. E. Goehringer, Ed Holt, Carl Sauer and Ray Wirt.

Detroit Section: John Randall, T. J. Crawford, R. H. Bennewitz and Jack Ogden.

The questions were rotated between all teams, each taking their turn, after which the other team had an opportunity to add to the answer. The 20 judges then scored electrically and results were recorded on a dial.

The trophy this year was donated by Taylor-Winfield, through member Walter Anderson and is arranged to permit the inscription of the name of the winning Section and the year.

This meeting usually is one of the high spots in the year's meeting program where the members can get answers to specific questions. Questions selected cover all types of welding. This meeting was no exception and interest was at a high point throughout the meeting.

Dayton

February 22nd was a big night for the Resistance Welding men of the Miami Valley. Eighty members and guests met in the Dayton Engineers Club to participate in a "Resistance Welding Forum." The forum moderator was T. Embury Jones, President of Precision Welder & Machine Co. of Cincinnati. After a general introduction to the subject by Mr. Jones, he called upon the four speakers of his panel of experts to present their particular branch of specialization.

John Quinn, Assistant Superintendent of Process at Delco Products, led off with a discussion of "Resistance Welding, A Production Process." He used a sample of the Delco shock absorber to show how the many processes of resistance welding were used in its manufacture. These included seam welding of the housing tubing, localized induction hardening of the piston shaft, hot upsetting of the mounting shaft and projection welding of the stone guard.

Siebert Schneider, Welding Engineer at Frigidaire, Plant No. 2, next presented "Applications of Resistance Welding." Mr. Schneider traced the application of welding on household refrigerators at Frigidaire since 1932, when the refrigerator was constructed with a wooden frame with no resistance welds, through 1933 when resistance welding was introduced, and then up to the present 1950 model which is extensively welded throughout. He pointed out that back in 1933 when the first 34 spot welders were installed, refrigerator production for that year was 224,000 and the welders had a total kva. name plate rating of 3000 kva. Last year refrigerator production reached 1,059,000 and at present 320 welders of all types are in use on all products, with a total demand of 53,000-kva. name plate rating.

William Bostwich, Chief Electrical Engineer at Precision next discussed "Power Supply for Resistance Welding." Mr. Bostwick showed why the nature of the resistance welder load created a problem for the power company and the plant engineer, and how the problem could be met with adequate power supply, proper location of supply and correct bus size and spacing. The impedance of the load was shown to be the prime factor in determining secondary voltage required, load demand and power factor.

Ralph Pelton, Service Welding Engineer at Precision rounded up the forum with some points on "Maintenance of Resistance Welding Machines and Controls." He stated that his experience has shown that most welder maintenance problems were due to a lack of fundamental understanding of the machines and the process. More interest should be shown in the subject, and the basic function of each machine part, be it mechanical, electrical, pneumatic or hydraulic should be mastered before becoming lost in seemingly complex details, he stated.

After this portion of the meeting, a lively general discussion period followed. Many specific problems were given to the "experts" for their solution and they did a commendable job in answering the questions. The moderator finally had to call a halt as the hour grew late.

So much interest and enthusiasm was exhibited by the group that Chairman Blankenbuehler promised more meetings on resistance welding next year.

Eastern Illinois

This newly formed Section held a meeting on February 22nd at the Plaza Hotel, Danville, Ill. L. C. Monroe, Editor of *Welders Digest*, Chicago, was the technical speaker. His subject was "Wherein Lies the Efficiency of Welding."

Hartford

The February 23rd meeting held at Rockledge Country Club, West Hartford, Conn., was addressed by Charles H. Jennings, Engineering Manager, Welding Dept., Westinghouse Electric Corp., on the subject "A.-C. and Rectifier Welders."

Indiana

The February 24th dinner meeting of this Section was held at the Chevrolet Commercial Body Works Cafeteria, Indianapolis. The meeting consisted of a plant tour and a general discussion both of which were of extreme interest to all. Of particular interest was the location of welding equipment with respect to the punch presses and other fabricating equipment as well as the method of power distribution. Approximately 125 participated in the plant tour which was arranged by R. T. Mortlock, Public Relations Director for the Chevrolet Commercial Body Works.

Kansas City

This Section held its regular monthly meeting on February 16th in the Advertising and Sales Executive Club. Technical speaker was Arthur B. Tesmen who spoke on the subject, "Contact Electrodes in Applications of Contact Welding." Mr. Tesmen presented the new developments in manual arc welding in a very interesting way with facts and figures.

Lehigh Valley

The Lehigh Valley Section of the AMERICAN WELDING SOCIETY and the American Society of Civil Engineers held a joint meeting Monday, March 6, at the Hotel Bethlehem, Bethlehem, Pa. A. E. Charlesworth, A.W.S. Section Chairman, presided at the meeting.

J. F. Willis, Engineer of Bridges and Structures for the Connecticut State Highway Department was the guest speaker. He gave a very interesting talk on "Welding of Highway Bridges." Mr. Willis told of the highway bridge building program in the State of Connecticut. His talk was illustrated with color slides showing many of the bridges in various stages of construction. He discussed the merits of welded and riveted bridges, both types having been erected throughout the State.

Eighty-five members and guests attended the technical session. A dinner meeting was held prior to the technical session, at which time a sound film entitled "Design of Arc-Welded Structures" was shown through the courtesy of the Lincoln Electric Co.

Los Angeles

On Thursday evening, January 19th, the Los Angeles Section held its regular monthly dinner meeting. The speaker was G. L. Revell, Welding Engineer, The Lincoln Electric Co., Los Angeles. The subject of Mr. Revell's talk was "Control of Warpage and Distortion in Welded Structures."

The speaker who collaborated in preparing the original films on arc welding, including the principles of warpage and distortion, first described the essential steps to be taken in analyzing such a problem. Especial attention was directed to the necessity of a thorough evaluation of all contributing factors to determine which would cause the greatest warpage. Slides were shown illustrating warpage effects created by heat, shape of welding groove, welding procedure and restraint. Innumerable means of counteracting each type

of warpage were described with the admonition of "Follow through on the original plan of warpage control so as to be better enabled to further analyze the problem."

Photographs of numerous shop and field weldments were projected on the screen while each warpage problem and how controlled were discussed. The subject and subsequent question and answer session was efficiently and interestingly presented, and reflected the speaker's many years of experience in handling welding problems.

Principles involved were further illustrated by showing of the Lincoln Electric Co.'s film "The Prevention and Control of Distortion in Arc Welding," which concluded the program.

Louisville

James M. Wilson, District Engineer, Metal & Thermit Corp., Pittsburgh, Pa., was the guest speaker at the February 28th meeting. His subject was "Thermit Welding and Its Current Applications."

Mr. Wilson traced the history of Thermit Welding from its introduction in this country in 1902, one of the early uses being the repairing of wrought iron locomotive frames. He told of the successful applications of the process for making rail joints for railroads and craneways, and told of a new method for welding rail joints in mines, that does not require preheat. One of the new uses mentioned was the repointing of bucket teeth used in digging iron ore. The talk was illustrated with a movie film entitled, "Mass Production by Thermit Welding." Lantern slides were used during the discussion period that followed the movie.

A social hour and a Dutch lunch followed the meeting.

Maryland

The February meeting of the Maryland Section held on the 17th was again attended by a record crowd, believed due to the activity of the Attendance Committee. While the dinner was attended by 46, the meeting itself drew 83 members and guests. A movie of the 1949 World Series was substituted for the usual "Coffee Talk." The technical session at first appeared to be handicapped by an unannounced last-minute substitution of speakers. Due to the illness of Mr. Raymo, the talk on "Heavy Weldments" was cancelled and Harry W. Pierce of the New York Shipbuilding Co. made an impromptu presentation of the welding of heavy sections. Although relatively unprepared, the talk held the attention of the audience, especially so when it switched over into the common sense approach of welding vs. casting or other fabrication methods. Mr. Pierce was able to demonstrate in the most interesting way the engineering approach to be taken to obtain minimum fabricating cost even though in some cases the method employed may be other than welding.

Michiana

The Michiana Section held an inspection trip through the Studebaker Corp. for their February meeting held on the 16th. Approximately 75 members and guests, several from other Sections, enjoyed the courtesies extended by Studebaker to present a very interesting program.

A film which is used as an indoctrination procedure for new employees was shown. This gave a general picture of many phases of producing a car, most of which were not to be seen in the subsequent trip. Unfortunately, the bulk of the welding is done in buildings which were not on the itinerary, but one flashwelder on fenders was seen in operation. Motor block line from foundry to finished car was followed.

Milwaukee

The last half of the Educational Program of the Milwaukee Section was present on February 6th and 13th with L. S. McPhee speaking on "How the Welder Enters into the Cost Picture" on February 6th. The last meeting was a quiz program to permit those attending the meeting to ask questions.

The monthly meeting on February 24th was addressed by L. Williams of the Lukens Steel Co. He presented a film showing how clad steels are produced and then explained some of the details of the methods used in joining clad steels. Cladding with stainless, nickel, inconel and copper was discussed.

The coffee talk was given by Lieutenant Commander Freundlich, a member of the Milwaukee Section. He presented an exciting picture of the life on submarines during the war.

New Jersey

The January 17th meeting was held at Essex House, Newark, as usual. It was a joint meeting with the A.S.M.E. Metropolitan Section. A large turnout for both the dinner and the technical session was gratifying to both the technical societies.

The film "Magic in the Air" concerning the advances of television was shown through the courtesy of the General Motors Corp.

Dr. J. T. Rettaliata, Dean of Engineering of the Illinois Institute of Technology talked on the "Gas Turbine Power Plant." By means of slides, he described the various types of gas turbine plants and outlined the functions of each part. The major portion of his talk dealt with the design and operation of the gas turbine, but the materials of construction and the method of fabrication also were mentioned.

The February 21st meeting was well attended at both the dinner and the technical session. The film "On to Jupiter" was shown through the courtesy of the General Motors Corp.

R. D. Thomas, Jr., Vice-President and Director of Research and Engineering, Arcos Corp., gave a very interesting talk on "Welding Stainless Steels and Other Alloys." He pointed out that although stainless steels as a class are generally welded to without difficulty still many peculiar results can occur when welding stainless steels to mild steel or in dissimilar combination. As a help in explaining difficulties encountered and in predicting results, Mr. Thomas illustrated by slides a method of estimating the analysis and resulting mechanical properties of the weld deposit. Considerable discussion was aroused by the talk.

New York

On February 14th, the New York Section of the A.W.S. and the New York Metropolitan Section of the Society of Naval Architects and Marine Engineers sponsored their annual joint meeting. At this meeting members of both Societies heard D. MacIntyre and G. O. Hoglund, Engineers, Alcoa Process Development Laboratories, Aluminum Company of America, New Kensington, Pa., speak on the subject, "Welded Aluminum Construction."

Mr. MacIntyre, who is in charge of marine sales development for Alcoa, spoke on the uses and applications of aluminum in the marine field. In his talk he described the historical growth of the use of aluminum for marine applications from the time about the turn of the century when aluminum was a novelty in the marine field, through the period from 1920 to about 1935 when aluminum was used principally in naval vessels, to the present day which finds increasing application for aluminum in merchant ship construction. Mr. MacIntyre also mentioned some of the latest recommendations of aluminum alloys for marine applications.

Following Mr. MacIntyre's paper on marine applications for aluminum, Mr. Hoglund spoke on the welding aspect of the subject. Mr. Hoglund, who is in charge of the Welding Section of the Alcoa Process Development Laboratories, described the various processes by which aluminum can be welded, and pointed out the applications and advantages and disadvantages of these processes. He described the effect of welding on the heat-treatable aluminum alloys thoroughly, and by an example of a test structure of a heat-treatable alloy fabricated by riveting and a similar welded structure, both of which failed at approximately the same load, he pointed out that this effect is not as serious as it may seem if properly provided for in the design. Mr. Hoglund showed a series of slides of different applications of fabrication of aluminum by welding.

Following dinner, and preceding the papers of the principal speakers, a motion picture entitled, "The Curiosity Shop," which showed the history of the development of aluminum, was shown.

J. Lyell Wilson, member of both societies, served as Technical Chairman.

Niagara Frontier

R. T. Gillette, Works Laboratory, General Electric Co., Schenectady, N. Y., was the guest speaker at the dinner meeting held on February 23rd at the Hotel Sheraton, Buffalo, N. Y. Mr. Gillette's subject "Resistance Welding—History, Design and Application" was one of the most interesting talks heard by the Section on the subject in some time. His discussion of the welding of aluminum to copper was probably the most outstanding part.

On April 21st and 22nd this Section will make its first attempt to hold a Sympo-

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sium, which will be held in cooperation with University of Buffalo and will be accompanied by exhibits of local manufacturers. Speakers now scheduled are: N. C. Jessen, Babcock & Wilcox Co., Control and Inspection of Alloy Welding; G. O. Hoglund, Alcoa, Design and Welding of Aluminum; R. D. Stout, Lehigh University, Introduction to Metallurgy of Welding; LaMotte Grover, Air Reduction, Welded Structural Design; L. C. Bibber, Carnegie Steel, Dimensional Stability; W. A. Stanley, Progressive Welder, Design for Resistance Welding.

Northern New York

The February meeting of this Section was held on the 23rd at the Circle Inn, Lathams, N. Y. In spite of the very inclement weather, a group of 40 people heard an excellent talk by Jack Ogden. His talk on "Welding Problems in the Automotive Industry," was well illustrated with numerous practical examples. It also gave a good perspective on production quantities and operations to those not familiar with this industry.

Oklahoma City

The February 21st meeting held at the Biltmore Hotel was addressed by Anthony K. Pandjiris who spoke on Weldment Design as it relates to the overall problem of producing economical weldments.

Philadelphia

The February 20th meeting was most interesting although it covered the slightly specialized subject of Resistance Welding.

H. J. Lange, Sales Engineer, National Electric Welding Machines Co., covered the subject of Resistance Welding, particularly its application, in a thorough manner, emphasizing his remarks with slides and exhibit of articles manufactured by Resistance Welding. The discussion following his talk brought out many interesting facts and problems in Resistance Welding.

The dinner before the meeting was highlighted by a Coffee speaker, Special Agent Kirkland of the Philadelphia Office of the F.B.I. spoke on the "Operation and Function of the F.B.I." The remarkable job that the F.B.I. is doing was well illustrated by the stories he told of actual cases in which they had been involved.

The panel discussion meeting held on Wednesday, March 1st, was a natural follow-up of the regular meeting. Any questions that remained on Reistance Welding were certainly solved at this panel on "Resistance Welding of Low Carbon Steels," headed by James MacKinney of the Budd Co. who was assisted by C. H. Benker of the General Electric Co. and Walter Mahl of the Heintz Mfg. Co. To add further to this discussion, C. D. Evans, Chairman, S. A. Greenberg, Technical Secretary and several other members of the A.W.S. Automotive Welding Committee which had an all day meeting in Philadelphia the same day, were present at the panel meeting.

Pittsburgh

The regular monthly meeting was held on February 15th at Mellon Institute. Dinner was served at the Hotel Webster Hall.

Howard S. Avery, Research Metallurgist, American Brake Shoe Co., Mahwah, N. J., presented an interesting, clear-cut talk on "Hard-Surfacing" by Welding (Fusion). A film on "Silver Alloy Brazing" was shown through the courtesy of Handy & Harman, which was also very good.

A discussion of the type of meeting to be offered to the members for the Tri-State Meeting on April 28, 1950 took place. Considerable interest was shown in presenting a highly educational, but entertaining program.

Rochester

This Section held their monthly meeting on Monday, February 20th, preceded by a dinner at Guy Michael's Restaurant.

The meeting opened with a film, "Dare Devils on Ice." A large delegation was present from the Niagara Frontier Section. Mr. Morrison of that Section challenged the Rochester Section to send a team to compete in a program called "Stump the Experts." This was accepted and the Rochester Section is looking forward to an interesting evening.

Air Reduction Sales Co. presented a lecture and demonstration of their Aircomatic process. Mr. Berryman of Airco gave a very inclusive résumé of the possibilities for progress, and the limitations of the process. This was followed by a fine demonstration of the process, with Steve Danes as operator. Everyone was invited to try his hand with the gun. There was a great deal of interest in the speed and versatility in welding aluminum.

Salt Lake City

A joint meeting of the A.S.M. and the A.W.S. local sections was held on January 26th at Newhouse Hotel, with an attendance of around 70. Speaker was Dr. W. G. Theisinger who spoke on "The Production, Fabrication and Application of Clad Steels." Dr. Theisinger has talked on numerous occasions before many technical societies throughout the United States. Due to recent industrial growth in this area, clad steels are only beginning to be specified and so this subject was of special interest and his presentation was undoubtedly among the best of its kind ever given here. A film, "A Visit to Lukens," was shown in conjunction with the talk and very well received.

The regular monthly meeting was held on February 9th in the Seagull Room, Temple Square Hotel.

Inasmuch as this is a new Section and very few of the local people are familiar with the objectives of the A.W.S. and particularly the value received from reading THE WELDING JOURNAL, the Program Committee decided to dispense with the entertainment feature preceding the technical session and instead had one of their members—Darwin J. Christofferson, Welding Engineer, Chicago Bridge and Iron Co.—present a brief discussion of an article from THE WELDING JOURNAL which is of local interest. Interest displayed in this part of the program was good and it is the plan of the Section to carefully select articles and properly present them at future meetings.

A round table discussion of Unionmelt and Heliarc followed. The Linde organization has a special kit and manual including many types of samples welded by both of these processes. E. E. Saville acted as narrator and read first from their sales manual on the subject of Unionmelt. Samples were passed around and the group was asked to in turn direct questions to H. C. Bell. Response was very active.

Next, Mr. Saville read from the manual on the Heliarc process. Samples were passed and questions directed to B. H. Higgs with equal enthusiastic response.

The original program was set up to include Powder Cutting, Flame Hardening and Allied Topics, but because of great interest and numerous questions, only two processes were covered in the allotted time.

San Francisco

A field trip to the Columbia Steel Co. plant, Pittsburg, Calif. took place on Tuesday, February 28th. The trip concluded with dinner at the plant. One hundred and seven members and guests enjoyed the afternoon visit to the plant and the dinner. The trip included the following points of interest at Columbia Steel: New Sheet and Tin Plate Mill; Open Hearth; New Rod Mill; Rolling Mill and Wire and Nail Mill.

Susquehanna Valley

The fifth monthly dinner meeting of the 1949–50 season was held on February 8th at the Hotel Berwick, Berwick, Pa.

John Hewill of Dallas, Pa., introduced Arthur Bolendar, Secretary of the Wyoming Valley Chamber of Commerce, who acted as coffee talker following the dinner. Mr. Bolendar emphasized the need to weld interests to provide a common objective in the industrial betterment of northeast Pennsylvania. He acknowledged that such nonpolitical organizations as the A.W.S. are an asset to the area and communities in which they function in providing the groundwork for technical thought and practice thereby putting local industry in a truly competitive position.

The technical speaker of the evening, Merrill S. Rosengren, development and sales engineer of the Stearns-Roger Mfg. Co., Denver, Colo., was introduced by Donald Howard, meeting chairman. Mr. Rosengren spoke on "Flame Hardening Principles and Applications."

The spinning, progressive and combination methods of flame hardening by the oxyacetylene-water quench technique was well illustrated with color movies and slide. The gradation from the surface flame-hardened area to the core was described by Mr. Rosengren as the result of this conduction method of hardening.

Speeds, gas consumption and initial equipment costs were briefly discussed

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which allowed parties to think along these lines in relation to their own shop's requirements.

A lively question period followed during which members and guests shared the discussion with the speaker and introduced problems for consideration of all present relative to the subject of flame hardening.

Tri State

February 23rd dinner meeting was held at the Hoosier Cardinal Cafeteria, Evansville, Ind.

After showing of 3 films on A.-C. & C.-C. Welding the audience was taken through the International Steel Co. plant and shown the work being done with Heliarc Welding and steel fabrication.

Tulsa

Dinner meeting was held on February 20th in the Main Private Dining Room of the Mayo Hotel. Technical speaker was Anthony Pandjiris, President of the Pandjiris Weldment Co., who spoke on Weldment Design. Topic covered the converting of castings to weldments.

Western Massachusetts

Regular monthly dinner meeting was held on February 14th at the Hotel Sheraton, Springfield, Mass. Frank E. Kessler spoke on "Tool and Die Welding."

Wichita

A buffet supper was served in the Rainbow Room of the Coleman Co. plant on February 13th.

A. B. Tesmen, Development Engineer, North American Philips Co., Inc., presented an illustrated address on "Contact Electrodes in Applications of Contact Welding." A live demonstration of contact electrodes in the Coleman plant was shown. This was a very interesting and educational meeting. The subject was well developed and was quite new to all.

Worcester

The February 21st meeting of this Section was held at the Tower House. Sixty members and guests were present to hear J. H. Cooper of the Taylor-Winfield Corp., present a paper on "Resistance Welding." The talk was illustrated by slides showing many new and unique applications of resistance welding, as well as new techniques employed. Mr. Cooper invited questions from the audience during the course of his talk. From the large number of questions submitted, it was clearly evident that the paper was of great interest to all those present.

A very interesting movie entitled "Snow Train" was shown before the technical session and refreshments were served directly after the meeting.

abstracts of
CURRENT WELDING PATENTS

prepared by V. L. Oldham

Printed copies of patents may be obtained for 25¢ from the Commissioner of Patents, Washington 10, D. C.

2,495,544—Pipe Welding and Magnetic Testing Apparatus—Robert A. Peterson, Dolph F. Heckle and John E. Clarke, Chicago, Ill., assignors to Magnaflux Corp., Chicago, Ill, a corporation of Delaware.

This patent relates to a longitudinal seam pipe welding and testing apparatus wherein a fixed position welding head is provided and it has means for moving a pipe having a longitudinal joint therein past the welding head to weld the longitudinal joint of the pipe. A support arm has a longitudinal end portion adapted for insertion into the pipe and a roller member is journaled on the inserted end of the support arm and is engageable with the internal surface of the longitudinal joint of the pipe at a point relatively behind the welding head with respect to the direction of movement of the pipe. A magnetizing coil is carried by the roller member and means for supplying current to the magnetizing coil connects thereto so that a magnetic field is established in the longitudinal welded joint of the pipe.

2,495,615—Welded Coupling—William W. Vander Clute, Elizabeth, N. J., assignor to Round Root Corp., Elizabeth, N. J.

Clute's coupling member is adapted to provide a fused welded coupling between a hollow member having an aperture for receiving one end of the coupling member and for engaging a metallic tubular member at its other end. The coupling member has a plurality of normally directed positioning elements on the exterior thereof adjacent one end for engaging the outer surface of the hollow member and positioning one end of the coupling member with the aperture in registering relationship with the inner surface of the hollow member during welding operations.

2,495,758—Welding Jig—Alfred G. Parker, Summit, N. J., assignor to Foster Wheeler Corp., New York, N. Y., a corporation of New York.

This patent covers a specialized jig used in the electric resistance welding together with the bodies of two articles each having a body with a peripheral edge, the bodies being of such shape and of such material that they are bendable in a direction away from one another without deformation of the bodies. The jig includes two separate work-holding members each having a passage therethrough with such passages being positioned in alignment when the two portions of the jig are placed in operative relation.

2,495,782—Welded Reinforcement—George L. Smith, United States Navy.

Smith's patent covers a method of reinforcing a metal plate, and the article produced, wherein the plate has an opening therein normally subjected to tensile loading in the direction of one axis of the opening. The reinforcing method comprises depositing welding electrode metal on the plate in the areas thereof along lines at angles of between approximately 20 to 30° to the said axis of the plate and spaced from the corners of the plate a distance substantially equal to the thickness of the plate. The corners referred to are those of the opening formed in the plate.

2,496,104—Hydropneumatic Pressure Booster and Welding Gun—Elmer F. Paner, Detroit, Mich.

The welding apparatus of this patent includes a body portion having a normally fixed electrode thereon. A pivoted carrier is provided on the body portion and positions an electrode therein. A pair of cylinders are on the carrier on opposite sides of the pivot of the carrier. Fluid pressure is provided for the pistons received in the cylinders in order to control the position of the movable carrier.

2,496,110—Double Rectilinear Torch Machine—Oliver Thurman, Jr., Mount Tabor, N. J., assignor to Air Reduction Co., Inc., a corporation of New York.

This patented apparatus includes a movable base carriage guided to move rectilinearly and an upper carriage movably mounted on the base carriage and guided to move rectilinearly at an angle to the direction of movement of the base carriage. A tracer and a torch are

mounted on the upper carriage and are capable of universal movement in a plane by reason of the double rectilinear movability of the carriages. Resilient means connect the upper carriage to the base carriage to transmit to the base carriage movements of the upper carriage in a direction in which the base carriage is movable.

2,496,188—Apparatus for Seam Welding of Tubing—Donald H. Wiese, Norristown, Pa., assignor to Superior Tube Co., Norristown, Pa., a corporation of Pennsylvania.

The apparatus of this patent includes soft heat-resistant plugs that internally engage and continuously yieldingly conform to a tubing at regions spaced longitudinally thereof to define an isolated zone in the tubing. Means are provided for applying heat to the seam edges of the tube to melt them within the limits of the zone and means are also provided for supplying gas under pressure to the zone to support the seam-forming metal while molten. These latter means include a small tube that extends longitudinally of the tubing to be welded with such small tube being attached to both of the first mentioned plugs.

2,496,313—Apparatus for Checking the Work of Arc Welders—Robert Sarazin, Neuilly-sur-Seine, France; vested in the Attorney General of the United States.

This patent covers a special type of a welder's shield which has an opening therein through which light rays pass. The shield has means thereon for supporting a light sensitive record receiving strip over the opening in the shield whereas a handle is provided for the shield and strip displacing means extend alongside the handle so that the operator's hand can simultaneously grasp the handle and operate the strip displacing means.

2,496,347—Inert-Gas-Blanketed Welding Rod Feed Process—Harry T. Herbst, Roselle, N. J., assignor to The Linde Air Products Co., a corporation of Ohio.

The patented process relates to inert-gas-blanketed arc-welding processes wherein the weld arc forms a weld puddle and such puddle is blanketed by an annular stream of nonoxidizing gas such as helium or argon. A filler rod is fed to the weld puddle along a path from a position remote from the puddle. The feature of the patent is to combine the supply of the blanketing gas with the feed of filler rod to the weld puddle in such a way as to prevent contamination of the weld puddle by oxygen carried by the filler rod.

2,496,779—Welding Apparatus and Control Therefor Actuated by an Electric Current Pulse Timer—Frans Hendrik de Jong, Eindhoven, Netherlands, assignor to Hartford National Bank and Trust Co., Hartford, Conn., as trustee.

This patent relates to a combination of different control apparatus wherein an electric current pulse timer means is provided in connection with a welding apparatus that has a pair of supply mains connected thereto. A relay is provided in the electric supply mains and it includes an energizing coil that is connected to one of the mains and to a stationary contact forming a part of the relay. A plurality of other contacts are provided in the relay and a contact selector means is operatively associated with the different contacts of the relay. Additional means are provided and are actuatable upon de-energization of the relay coil for moving the contact selector means past the stationary contacts in stepwise movement.

2,497,260—Electrical Control for Fence Welding Machines—Harry E. Griesemer, Bloomington, Ill., assignor to Northwestern Steel and Wire Co., Sterling, Ill., a corporation of Illinois.

This patent covers a specialized electrical control for machines of the type indicated. The machine is adapted to apply successive cross wires to the line wires, squeeze such wires between the electrodes and apply a controlled welding current to the wires.

2,497,629—Shielded Arc Welding—Perry J. Rieppel, Worthington, Ohio, assignor by mesne assignments, to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

Rieppels welding method comprises maintaining an arc by supplying electric current from a source, and surrounding the arc with a blanket of foam including a gaseous medium.

2,497,631—Arc Welding—Gilbert R. Rothschild, Somerville, N. J., assignor to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

This patented arc welding method comprises striking an arc between the workpiece and an electrode and delivering a gaseous shield to the arc. This shield comprises a mixture of from 1 to 10% of hydrogen and the remainder a rare gas of the atmosphere other than helium.

LIST OF NEW MEMBERS

February 1 to February 28, 1950

ANTHONY WAYNE

Bollinger, W. B. (C)

ARIZONA

Aspey, Frederick Morris (B)
Garland, William T. (B)
Marks, Byron O. (C)

BIRMINGHAM

Greene, S. W. (C)

BOSTON

Boudreau, Arthur J. (C)
Christensen, Nils (B)
Cloutier, Omer G. (C)
McGlew, Thomas G. (C)

CHATTANOOGA

Machacek, Rudolph J. (C)

CHICAGO

Arntzen, Edward F. (C)
Chartier, Lloyd J. (B)
Gurley, Robert H. (B)
Hale, Robert S. (C)
Hanzl, Roman J. (C)
Hermann, Robert A. (C)
Lilly, William C. (C)

CINCINNATI

Lengel, Leo (B)

CLEVELAND

Downer, Hugh C. (B)
Kacir, Ernest Emery (C)

COLUMBUS

Barta, Irvin M. (D)
Bovie, David F. (D)
Kline, Robert G. (C)

DAYTON

Alridge, Martin (C)
Brukner, Clayton (C)
Carson, Charles E. (D)
Dunn, Howard T. (D)
Green, William A. (D)
Holden, Harvey R. (D)
Howard, Willard (D)

DETROIT

Cooney, Robert T. (C)
Smith, Theodore C. (C)
Stallard, Ralph M. (C)

HOUSTON

Barnes, Homer C., Jr. (C)

INDIANA

Burleson, Paul C. (C)
Lewis, E. M. (B)
Plemen, Joseph F. (C)
Schaefer, Michael G. (B)

KANSAS CITY

Fitzjarrell, Roy V. (C)

LONG BEACH

Carroll, Charles E. (C)
Laughlin, B. T. (C)
Lomeli, Jerry (C)
McKiney, Clifford T. (C)

LOS ANGELES

Grillo, Frank (B)
Healy, Arthur C. (C)
Kerzner, Mirko J. (B)
Skewis, W. H. (B)

LOUISVILLE

O'Regan, Joseph (B)

MARYLAND

Antonelli, Joseph A. (C)
Boldtman, Alfred H. (C)
Embly, Robert (C)
Feimer, Peter J. (C)
Gossard, Robert I. (C)
Grego, John R. (C)

Hartman, Charles E. (C)
Johnston, Frederick (C)
Jordan, Raymond W. (C)
Lucey, T. J. (C)
Saberg, Harold E. (C)
Young, Herbert M. (C)

MICHIANA

Morris, Charles A. (B)

MILWAUKEE

Adkins, Howard E. (D)
Wiese, Russell Edwin (C)

NEW JERSEY

Mannion, James V. (C)

NEW YORK

Migel, Hamilton (B)
Molloy, John Francis, Jr. (C)
Seiden, A. L. (C)
Stewart, John T. (A)
Turitzin, Alexander Michail (C)
Wherry, William R. (B)

NIAGARA FRONTIER

Strate, F. R. (B)

NORTHERN NEW YORK

Lehmone, O. Arthur (D)
Sadler, Louis (D)
Van Natten, Wesley J. (C)

NORTHWEST

Collom, Merton P. (B)
Martinson, Paul H. (B)
McDonald, Ralph O. (B)
Mellberg, Oscar N. (C)

NORTHWESTERN, PA.

Swartzfager, Laverne R. (C)

PHILADELPHIA

Wentzel, A. L. (A)
Wiese, Donald H. (B)

PITTSBURGH

Burke, James E. (C)
Vanderbeck, Richard W. (C)

RICHMOND

Thayer, Raymond L., Jr. (B)

ROCHESTER

Burger, Melvin John (C)

ST. LOUIS

Rueff, Robert C. (C)

SALT LAKE CITY

Newell, Donald J. (B)
Shannon, W. B. (B)
Spencer, Claude E. (B)

SAN FRANCISCO

Joyce, Fred W., Jr. (B)

SYRACUSE

Cohen, Max Morris (C)
Fitzgerald, Arnold W. (B)
Jeschke, Ernest (C)
Kotsen, Alfred J. (B)

WASHINGTON

Griffin, Thomas J. (C)
Smith, Wayne (C)

WICHITA

Rodenberg, Edward E. (D)

WESTERN MASS.

Potorski, Louis J. (C)
Oakes, Charles M. (B)

WORCESTER

Moore, Roger W. (B)

NOT IN SECTIONS

Amos, W. A. (C)
Higgins, Wallace L. (B)
Miller, Conway Adam (D)
Parsons, Reginald Ainslie (D)

Members Reclassified

During the month of February

Claussen, Gerard E. (C to B)

New Literature

(Continued from page 338)

New Best's Safety Directory Ready

The new "Best's Safety Directory for 1950–51," covering the entire field of safety, fire protection and control, hygiene, first-aid and sanitation, is now available according to an announcement of Alfred M. Best Co.'s Safety Engineering Division.

The Directory is unique in that it combines all the best practical features of a safety manual, directory, index, encyclopedia and catalog into one comprehensive, profusely illustrated, 511-page volume.

It is often called the "What, How and Where Book of Safety"—showing what safety products or devices to use for specific hazards; how to use them; where to get them.

One outstanding feature of the new Directory is its indexing and subject-grouping system. These devices, plus countless illustrations, make it easy to locate safety products even when the user is not certain of the type or name of the product he needs. The logical arrangement of subjects also serves as a checklist of hazards—many of which are frequently overlooked. Typical sections are Arm and Hand, Body and Leg, Eye and Face, Fire, etc.

The book is priced at $5.00—with lower rates for quantities. It may be obtained from the home office of the Alfred M. Best Co., 75 Fulton St., New York 7, or branch offices in Atlanta, Boston, Chattanooga, Chicago, Cincinnati, Dallas and Los Angeles.

Data on Safety Equipment

The 1950 issue of "Everything in Safety," a catalog of personal protective equipment and industrial safety devices, has just been released by the General Scientific Equipment Co., 2700 W. Huntingdon St., Philadelphia 32, Pa.

This new catalog covers, respiratory devices, eye protection, hats, gloves, carboy pumps, drum pumps and miscellaneous industrial safety equipment for use in industries, mines, utilities and farms. It is 46 pages, fully illustrated, and includes price list. Copy sent free on request.

Repairing Worn Buckets

Rebuilding and repairing worn buckets quickly and inexpensively with Manganal 11 to 13½% Manganese-Nickel Steel products is the subject of an informative folder now available upon request from Stulz-Sickles Company, 134 Lafayette St., Newark 5, N. J.

Manganal, a special-analysis of manganese-nickel steel, is best described as "the toughest metal known, not harmed by heat." Wherever the wear on the bucket, one or more of the Stulz-Sickles products will do an excellent rebuilding and repairing job.

Employment Service Bulletin

Position Vacant

Welding Engineer with Metallurgical Training. Development experience desirable on nonferrous metals, including use of protective atmospheres. Assistant for above engineer also needed. Please write directly to E. W. Doty, Assistant Employment Directors, Los Alamos Scientific Laboratory, Los Alamos, N. M.

Services Available

A-596. Graduate engineer with 24 years' manufacturing experience; past 14 on all types heavy coated arc-welding electrodes. Thorough knowledge of equipment, materials and processes. Familiar with all management details including purchasing, accounting, process control, labor relations, job evaluations, etc. Age 49.

A-597. Metallurgical Engineer, age 30. Steel mill production control and foundry experience. Development and installation of machine welding and scarfing equipment. Supervisor of heat treating shop. Metal finishing and sheet metal experience.

A-598. Operating Management or Administrative Executive. Age 36. Sound, substantial experience in engineering, welding and industrial management. Chief Engineer, Director of Engineering (multiplant), Works Manager. Steel manufacture, fabricating and assembly—welded and riveted, job shop and production line. Successfully solved severe labor relations problems. Registered Engineer—Pennsylvania.

WELDING RESEARCH COUNCIL

of the Engineering Foundation

Sponsored by the American Welding Society and American Institute of Electrical Engineers
American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers
American Society of Mechanical Engineers, and Society of Naval Architects and Marine Engineers

Supplement to The Welding Journal, April, 1950

Tensile Tests of Internally Notched Plate Specimens

Physical behavior at various temperatures of internally notched 3/4-in. thick, 12-in. wide flat plate specimens including maximum loads, strain energy and mode of fracture. Part II deals with effect of ratio of width divided by thickness of plate

by Samuel T. Carpenter and Wendell P. Roop

Part I

INTRODUCTION

THE object of the tests related in this report was to investigate the physical behavior at various temperatures of a large number of 12-in. wide, full-thickness specimens of steel plate. The specimen contains a centrally located internal notch 3 in. wide terminating with a jeweler's hack saw cut 1/8 in. long and 0.010 in. wide (see Fig. 30, Appendix I). All tests were made with tension loading applied in the direction of rolling.

The physical behavior of the steels with respect to maximum loads, strain energy and mode of fracture was investigated with the principal purpose of establishing transition temperatures based upon 12-in. wide, 3/4-in. thick specimens.

The steel tested has been studied by several laboratories and has been designated as "A," "C," "Br" (B as-rolled), "Bn" (B normalized), "Dn" (D normalized), "E" and "Q." These were 6- x 10-ft. plates, all 3/4 in. thick except Q steel which was 5/8 in. thick. All but Q have been tested.

The chemical analyses of the steels tested, as previously given on page 35 of the Pennsylvania State College Report,[2] are as follows:

Chemical Analyses

Steel	C	Mn	P	S	Si	Al	Ni	Cu	Cr	Mo	Sn	N_2
						%						
A	0.26	0.50	0.012	0.039	0.03	0.012	0.02	0.03	0.03	0.006	0.003	0.004
Br	0.18	0.75	0.008	0.030	0.07	0.015	0.05	0.07	0.03	0.006	0.012	0.005
Bn	0.18	0.73	0.011	0.030	0.04	0.013	0.06	0.08	0.03	0.006	0.015	0.006
C	0.24	0.48	0.012	0.026	0.05	0.016	0.02	0.03	0.03	0.005	0.003	0.009
Dr	0.22	0.55	0.013	0.024	0.21	0.020	0.16	0.22	0.12	0.022	0.023	0.006
Dn	0.19	0.54	0.011	0.024	0.19	0.019	0.15	0.22	0.12	0.021	0.025	0.006
E	0.20	0.33	0.013	0.020	0.01	0.009	0.15	0.18	0.09	0.018	0.024	0.005

The fullest use has been made of reports from the University of California,[1] the University of Illinois[2] and Pennsylvania State College[3] as an aid to instrumentation and as an aid in the preliminary determination of the transition temperature.

INSTRUMENTATION

Elongation Measurement

To determine strain energy it was necessary to measure the elongation of the test specimens. The gage length was established as three-quarters of the width of the plate, or 9 in., with the ends of the gage length 4 1/2 in. above and below the notch. The instrument developed permitted a determination of the elongations of the plate in both the elastic and plastic range. Bakelite SR-4 gages are used in these instruments. The elongations were measured over twelve separate gage lines.

Samuel T. Carpenter and **Wendell P. Roop** are connected with the Division of Engineering, Swarthmore College, Swarthmore, Pa.

Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

The work herein reported is part of a research project sponsored by the Bureau of Ships, U. S. Navy. The opinions expressed are those of the authors, not of the sponsor.

Five of the gage lines were on each of the 12-in. faces of the plate and two of the gage lines were on the edges. The five gage lines on the face of the plate were located as follows: one at the longitudinal center line of plate, two $1^1/_2$ in. either side of the center line, and two $3^3/_4$ in. either side of the center line. The elongation for each gage line was determined separately. The instruments used and the details of mounting them are fully described in Appendix I.

Preparation of Notch

Careful attention was given to the preparation of the notch. The accepted procedure at all laboratories where wide full-thickness plate tests had been made was to use a jeweler's hack saw to establish the acuity of the notch. To provide uniform acuity, the width of the last $^1/_8$ of an inch of the notch on both sides of the internal notch was specified to be 0.010 in. See layout of notch in Appendix I. A jig saw was utilized to make the jeweler's hack saw cut. This machine is described in detail in Appendix I.

Temperature Control Chamber

The temperature control chamber was

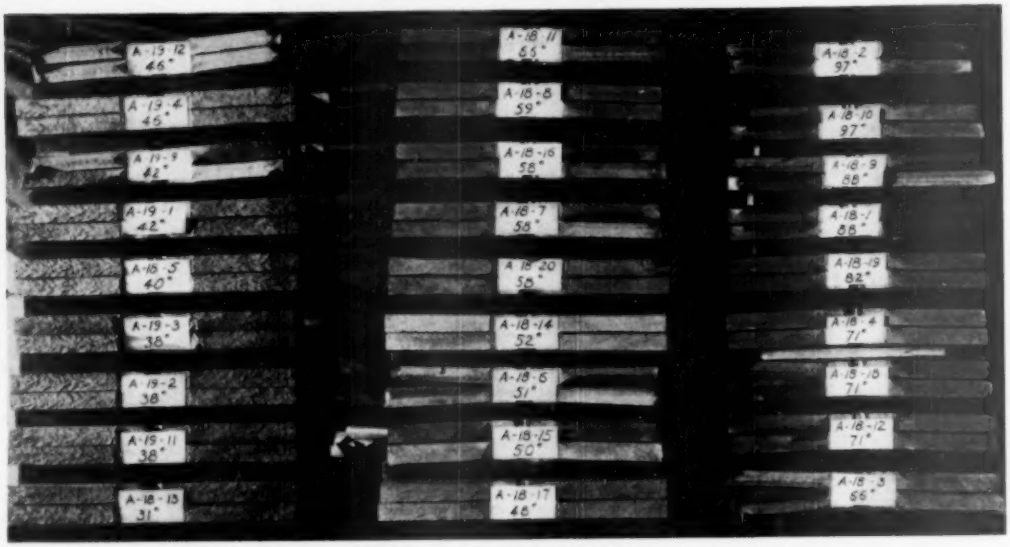

Fig. 1 "A" steel, photograph of fracture surfaces

Table 1—"A" Steel, Tests of Specimens 12 In. Wide, $^3/_4$ In. Thick with Standard Notch

(The notch is 3 in. wide and has at its extremities a cut $^1/_8$ in. long and 0.010 in. wide made with a jeweler's hack saw)

		Visible crack		*Maximum load*		*Failure*		
Spec. No.	*Temperature, °F.*	*Energy, in.-lb.*	*Load, lb.*	*Energy, in.-lb.*	*Load, lb.*	*Energy, in.-lb.*	*Load, lb.*	*Type of failure, % shear*
A-18-13	31	6,500	247,500	13,800	248,500	13,800	248,500	0
A-19-11	38	1,100	230,000	29,300	283,000	29,300	283,000	0
A-19-2	38	5,800	240,500	22,800	265,400	22,800	265,400	0
A-19-3	38	6,400	245,000	61,600	312,500	61,600	312,500	10
A-18-5	40	4,200	241,000	21,900	270,300	21,900	270,300	0
A-19-9	42	4,000	230,000	95,900	231,600	234,500	60,000	100
A-19-1	42	2,800	230,000	22,400	265,500	22,400	265,500	0
A-19-4	46	1,100	230,000	24,400	256,000	24,400	256,000	0
A-19-12	46	1,200	230,000	117,300	328,000	249,200	131,000	100
A-18-17	48	10,300	235,500	43,100	283,000	43,100	283,000	0
A-18-15	50	11,200	248,000	100,900	319,500	240,900	80,000	100
A-18-6	51	7,800	241,500	91,500	322,000	236,300	67,000	100
A-18-14	52	4,000	234,500	20,700	265,000	20,700	265,000	0
A-18-20	58	8,500	240,000	31,000	274,000	31,200	274,000	0
A-18-7	58	14,100	250,000	92,400	319,500	233,900	68,000*	100
A-18-16	58	8,300	235,000	100,500	319,000	250,600	72,000*	100
A-18-8	59	11,700	243,700	91,100	318,000	232,160	52,000*	100
A-18-11	66	18,700	253,000	104,600	315,000	229,400	58,000	100
A-18-3	66	12,800	243,000	92,800	314,300	234,000	50,000	100
A-18-12	71	17,100	250,000	86,400	314,400	247,100	95,000	100
A-18-18	71	16,600	250,000	104,300	317,000	263,700	15,000	100
A-18-4	71	10,100	243,000	84,700	312,500	232,700	76,500	100
A-18-19	82	10,900	237,600	99,700	314,000	274,000	90,000	100
A-18-1	88	12,600	238,000	82,400	312,200	237,900	50,000	100
A-18-9	88	11,300	240,000	98,100	314,500	255,600	50,000	100
A-18-10	97	15,300	248,500	93,000	314,000	230,000	50,000	100
A-18-2	97	12,400	238,000	92,600	311,500	263,700	50,000	100

* Indicates that this was not the load at fracture, but is given as the last load immediately preceding fracture.

made of Plexiglas, so that the specimen and instruments would be visible at all stages of the test. Strip heaters were installed to give temperatures above that of the laboratory. Two fans at the top of the box insured the circulation of the heated air. Cooling was obtained by blowing air over dry ice and conducting this cool air to the Plexiglas box by insulated ducts. This installation is described and illustrated in Appendix I.

Measurement of Temperature

The temperature was determined by the use of thermocouples. Three thermocouples are mounted on each specimen, one in the $^3/_4$-in. drill hole in the center of the plate, one $5^1/_2$ in. above the notch in the center of the plate and the third one located $^1/_8$ in. from the end of the notch immediately above the junction of the standard and jeweler's hack saw cuts. A fourth thermocouple determined the ambient temperature within the box. A complete description of the instrumentation with photographs of the various pieces of apparatus is contained in Appendix I.

The temperature at the $^3/_4$-in. drill hole has been used in interpreting all tests.

SPECIMEN IDENTIFICATION

The locations of the specimens in the 6- x 10-ft. plate are shown in the upper left-hand corner of the figures giving load and energy data for each steel. Upon the arrival of the 6- x 10-ft. plates, they were placed in a rack, each slot of which was numbered. Therefore, the number A-18-8 means that it is the 12-in. wide, 24-in. long specimen from the plate of A steel racked in slot 18, and its position within the 6- x 10-ft. plate was No. 8. This method of cutting the plate gives eight specimens from the outside edges of the plate, four specimens in the central area of the plate and eight specimens for the intermediate positions in the plate for a full size 6- x 10-ft. plate.

TESTING PROCEDURE

The general method of testing was to load the specimen to 10,000 lb. and determine the initial readings of the elongation gages. The load was then increased to 190,000 lb. and the gages read. The load was then reduced to 10,000 lb. and the initial readings were checked. The test was then started by increasing the load to 190,000 lb. and proceeding from this load by load increments which produced approximately equal steps of deformation as measured by the edge gages. The total load and the elongation on all gage lines was then determined. During every series of elongation readings the pump of the testing machine was cut off. If the load on the specimen fell off due to plastic deformation, high- and low-load readings were made. In plotting load-elongation curves the high load has been used.

Load-elongation curves for representative specimens are given in Appendix II.

"A" STEEL

Figure 1 shows the fracture of all 27 specimens of the A steel. It is noteworthy that fractures of the A steel were usually either 100% shear or 100% cleavage failures. Attention should also be called to the symmetry of the fractures. The mode of fracture, cleavage or shear was very similar on both sides of the notch except for six specimens where a shear failure in a single plane occurred on one side and

Table 2—"A" Steel, Tests of Specimens 12 In. Wide Made at University of California

*Spec. No.**	*Temp., ° F.*	*Energy to max. load, in.-lb.*	*Type of failure, % shear*
A-5	(−9)-(−8)	14,400	0
A-41x	7–8	19,000	0
A-4	11	16,300	0
A-42x	19	15,000	0
A-2	31–33	104,000	26
A-3	50	96,000	100
A-1	86	98,000	77

* These are the designations of plates assigned by the University of California as described in their final report.[1]

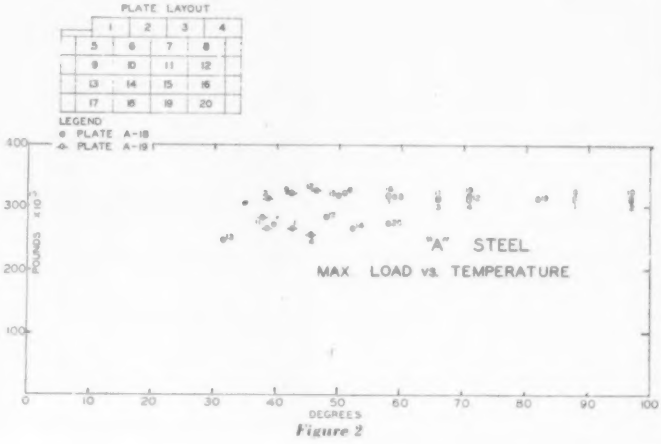

Figure 2

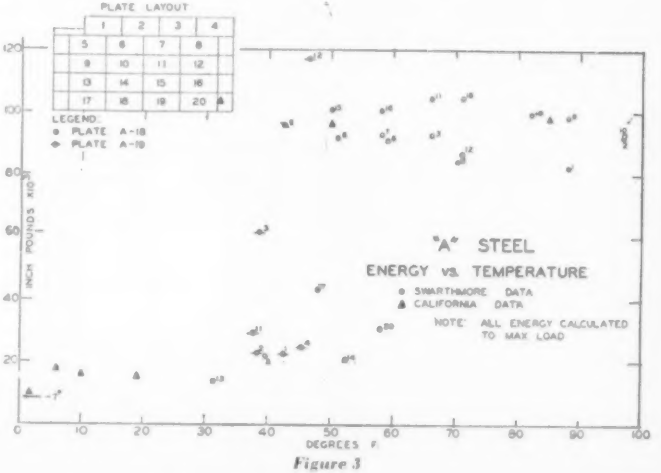

Figure 3

a double plane shear failure occurred on the other side of notch. Shear failures progressed outward from each end of the notch at the same rate.

Table 1 gives the load and the energy in in.-lb. to the first visible crack, to maximum load and to failure. It also gives the temperature and the type of failure in terms of the per cent of shear failure within the 9 in. net width. Table 2 shows in tabular form the data on energy to maximum load obtained at the University of California[1] on 12-in. wide plates.

Figure 2 shows the maximum loads plotted as ordinates with temperatures as abscissas. In Fig. 3, energies to maximum load are plotted as ordinates with temperatures as abscissas. The data obtained at the University of California[1] on plates 12 in. wide are superimposed on the Swarthmore data. Figure 4 is a plot of the percentage of shear failure in the various specimens of A steel.

The decision to include data on load and energy to the first visible crack deserves some explanation. It was visually observed that the first sign of fracture generally occurred at the mid-thickness of the plate. The load to produce the visible crack varied only slightly with the specimen for a given type of steel and seemed to be independent of the type of fracture which occurred later.

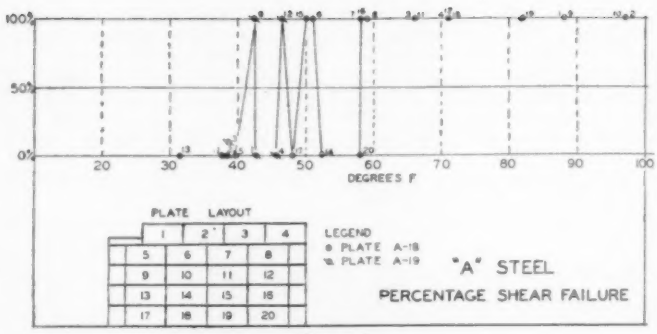

Figure 4

"C" STEEL

Type of Fracture

The behavior of the C steel was very erratic. The fractures of many of the C steel specimens are shown in Fig. 5. There are instances of cleavage fracture followed by shear fracture, cases of shear fracture followed by cleavage fracture, and other cases where cleavage is followed by shear which is followed in turn by cleavage fractures. These mixed types of fracture occur over wide ranges of temperature. The fractures in almost every specimen

Fig. 5 "C" steel, photograph of fracture surfaces

Table 3—"C" Steel, Tests of Specimens 12 In. Wide, 3/4 In. Thick with Standard Notch

(The notch is 3 in. wide and has at its extremities a cut 1/8 in. long and 0.010 in. wide made with a jeweler's hack saw)

		Visible crack		*Maximum load*		*Failure*		
Spec. No.	*Temperature, °F.*	*Energy, in.-lb.*	*Load, lb.*	*Energy, in.-lb.*	*Load, lb.*	*Energy, in.-lb.*	*Load, lb.*	*Type of failure, % shear*
C-24-7	63	1,700	256,300	18,600	287,500	18,600	287,500	0
C-24-19	63	15,100	273,000	32,600	281,000	32,600	252,000	0
C-24-14	73	15,100	275,000	29,200	316,000	29,200	316,000	0
C-24-17	73	40,400	286,000	40,400	286,000	140,100	72,500	65
C-24-5	74	2,000	227,700	42,000	291,700	151,400	60,000	59
C-24-13	78	12,100	267,500	40,500	295,000	40,500	295,000	0
C-24-8	81	4,300	261,500	97,600	308,300	114,600	298,000	15
C-24-20	82	15,700	276,000	42,800	291,200	57,100	236,800	0
C-24-6	88	4,500	255,500	55,200	310,700	137,100	147,000	40
C-24-15	88	15,900	275,500	49,700	293,000	49,700	293,000	0
C-24-18	89	33,400	292,000	33,400	292,000	45,200	278,700	0
C-24-10	96	22,500	287,500	69,700	311,500	147,300	54,000	58
C-24-2	97	1,900	248,500	87,300	308,500	205,300	17,000	71
C-24-9	107	15,500	271,000	91,200	321,500	278,800	75,000	89
C-24-1	108	3,900	249,000	128,900	370,000	268,900	216,400	63
C-24-3	116	5,800	254,500	130,600	360,000	238,300	50,000	100
V-24-11	116	30,100	300,000	117,000	371,500	329,200	60,000	100
C-24-4	124	10,100	262,500	104,200	369,000	299,400	80,000	100
C-24-12	124	8,500	250,000	95,300	344,100	236,700	59,000	92
C-24-16	130	14,200	275,000	91,300	374,000	291,200	100,000	100

were symmetrical about the center line and had the characteristic "thumbnail."

Table 3 gives the load and the energy in in.-lb. to the first visible crack, to maximum load and to failure. It also gives the temperature and the type of failure in terms of the per cent of shear failure. Table 4 shows the data on energy to maximum load obtained at the University of California[1] on 12-in. wide plates.

Figure 6 shows the maximum loads as ordinates and Fig. 7 shows the energies to maximum load as ordinates, with temperatures as abscissas in each case. Again, the data obtained at the University of California[1] on plates 12 in. wide are superimposed. Figure 8 represents a plot of the per cent of shear failure observed in each specimen. The abscissas in these curves are temperatures and the ordinates are percentages of shear failure computed on the basis of the net width of 9 in.

It is of great interest to note that there are often two load maxima in the load elongation curves. The first maximum is the load at which a cleavage fracture occurs, extending over only a part of the cross section. When this type of fracture occurs the load drops, and if the load is increased again there is a second maximum. This may be at a load higher or lower than the first. The specimen may then fail by cleavage or continue to yield.

"Bn" STEEL

Nineteen specimens of Bn steel were tested, their fracture surfaces being shown in Fig. 9. All these fractures started with an initial shear zone, although in the case of specimens 1 and 7 the zone was small. Examples of the initial shear zone may be seen on the right halves of specimens 4 and 11 where the small dark patches at the end of the notch indicate the presence of a shear area.

Table 5 gives the data for the Bn steel.

Figure 10 gives the maximum loads as ordinates, Fig. 11 the energies to maximum load as ordinates and Fig. 12 the per cent shear, with temperatures as abscissas in each case. Data taken at the University of California[1] are given in Table 6 and the values are plotted in Fig. 11.

The Bn shear specimens exhibited along their fracture surface striations composed of many small "terraces" mainly to be found around the mid-thickness of the specimen. These "terraces" interrupt the shear surface as flat areas parallel to the specimen surface and are of the order of 1/64 in. wide. It can be noted at this time that the Br steel when fractured exhibite l definite striation bands with a middle zone appearing coarser in texture. The "terraces" mentioned for Bn steel are undoubtedly associated with these characteristics found in Br steel.

"Br" STEEL

The fracture surfaces of the 16 speci

Table 4—"C" Steel, Tests of Specimens 12 In. Wide Made at University of California

*Spec. No.**	*Temp., ° F.*	*Energy to max. load, in.-lb.*	*Type of failure, % shear*
C-1	32–33	13,400	0
C-2	81	20,300	3
C-52x	90	72,000	10
C-3	101	85,000	51
C-51x	120–123	93,000	100
C-11x	132–136	83,000	93
C-5	141–145	78,000	91

* These are the designations of plates assigned by the University of California as described in their final report.[1]

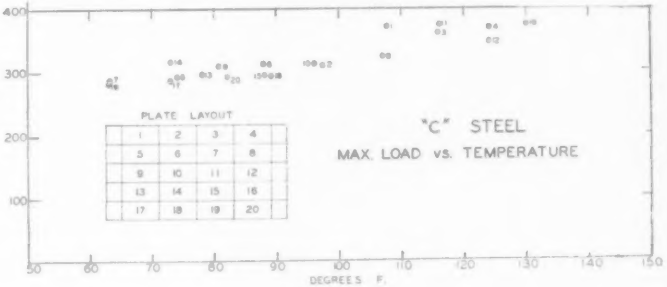

Figure 6

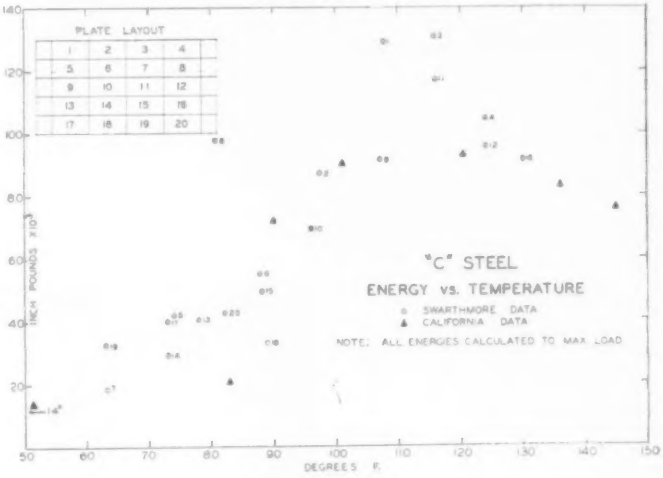

Figure 7

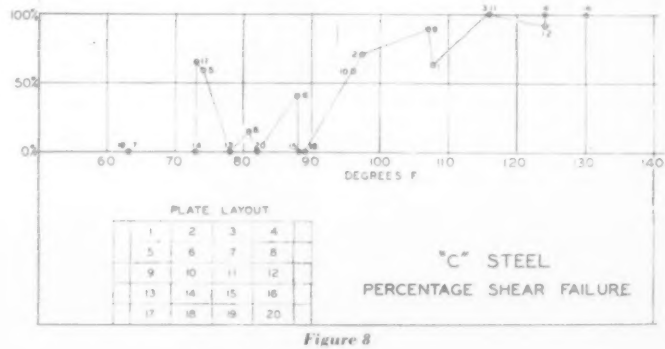

Figure 8

Table 5—"Bn" Steel, Tests of Specimens 12 In. Wide, 3/4 In. Thick with Standard Notch

(The notch is 3 in. wide and has at its extremities a cut 1/8 in. long and 0.010 in. wide made with a jeweler's hack saw)

		Visible crack		First maximum		Second maximum		Failure		Type of failure, % shear
Spec. No.	Temp., ° F.	Energy, in.-lb.	Load, lb.	Energy, in.-lb.	Load, lb.	Energy, in.-lb.	Load, lb.	Energy, in.-lb.	Load, lb.	
Bn-21-7	−8 9	4700	238,000	41,500	272,000	...	...	41,500	272,000	0
Bn-21-1	−1 2	7700	240,000	32,900	270,800	...	...	32,900	270,800	0
Bn-21-8	1 2	6300	242,000	41,300	283,400	44,500	279,400	44,500	279,400	1
Bn-21-2	9 1	6400	238,700	59,700	295,700	...	...	59,700	290,000	3
Bn-21-9	9 2	7700	240,500	53,900	289,300	...	...	53,900	289,300	3
Bn-21-18	9 9	4900	243,400	30,000	274,000	...	...	39,000	274,000	0
Bn-21-6	10 0	4000	240,000	137,000	326,300	...	...	309,100	50,000	100
Bn-21-14	10 0	4600	245,100	49,200	292,500	51,000	288,000	57,000	288,000	2
Bn-21-10	18 9	5200	236,300	70,200	309,000	...	...	70,200	309,000	3
Bn-21-3	19 8	6500	234,800	125,600	321,800	...	...	266,700	199,000	66
Bn-21-4	23 8	3300	227,500	56,100	299,400	...	...	56,100	299,400	3
Bn-21-11	24 5	6400	234,800	60,600	294,700	...	...	60,600	294,700	3
Bn-21-15	25 3	5900	233,800	29,800	263,500	...	...	29,800	263,500	1
Bn-21-12	29 4	6400	234,500	121,500	318,900	...	...	293,500	25,000	100
Bn-21-17	29 8	5700	234,900	120,000	317,700	...	...	290,400	50,000	100
Bn-21-16	29 9	4700	237,600	118,200	320,400	...	...	295,600	22,000	100
Bn-21-20	30 2	4900	235,500	119,000	324,800	...	...	294,000	40,000	100
Bn-21-19	41 3	3400	229,800	123,500	316,000	...	...	287,200	30,000	100
Bn-21-5	73 8	3800	222,500	115,000	310,000	...	...	292,500	41,000	100

mens of this steel as shown in Fig. 13 are characterized by cleavage fracture of a very coarse appearance, which has not been observed in the other project steels tested at Swarthmore. The shear mode of failure is also unique in that it almost always exhibited a double striation along the fracture, as is shown for example, in Fig. 14. The word striation has been used here in an attempt to avoid misleading the reader as to the nature of this effect, which has been variously called lamination, banding, fissuring, etc., by visitors to the Swarthmore laboratory. In Fig. 14, three zones of approximately equal thickness may be seen, giving the fracture the appearance of a sandwich. Near the notch localized separation characteristics of laminations may be noted.

Table 7 gives the data for Br steel. The maximum loads are plotted as ordinates in Fig. 15, energies to maximum load as ordinates in Fig. 16 and per cent shear as ordinates in Fig. 17, with temperatures as abscissas in each case. The energy plot also includes the data taken at the University of California,[1] and shown in Table 8.

Table 6—"Bn" Steel, Tests of Specimens 12 In. Wide Made at University of California

Spec. No.*	Temp., ° F.	Energy to max. load, in.-lb.	Type of failure, % shear
B-8	(−12)-(−10)	22,000	0
B-21x	10	53,000	0
B-10	10–15	116,000	87
B-2	32–36	134,000	78
B-5	50–51	121,000	100
B-4	80	133,000	94

* These are the designations of plates assigned by the University of California as described in their final report.[1]

"Dn" STEEL

Figure 18 presents the fracture surfaces of the nineteen Dn specimens, six of which are all shear, nine all cleavage (except for an initial shear zone) and four specimens (Nos. 2, 8, 12, 17) have mixed fractures changing from an initial shear to a cleavage failure. In the case of Specimen 17, one side remained shear while the other altered from shear to cleavage. Specimens 2 and 8 were very similar in their performance, each starting to fracture with a single shear surface on one side of notch and a double shear surface on the other side of notch. These two specimens fractured in the cleavage mode after the maximum load was reached. Table 9 gives the Swarthmore data for Dn steel. Univer-

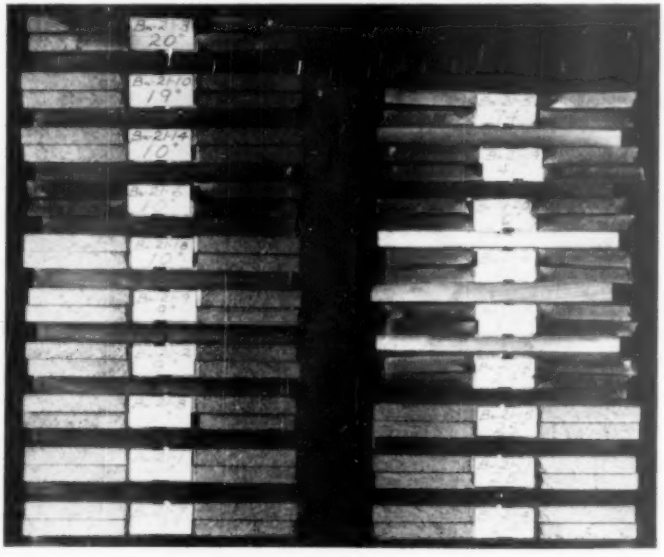

Fig. 9 "Bn" steel, photograph of fracture surfaces

Table 7—"Br" Steel, Tests of Specimens 12 In. Wide, 3/4 In. Thick with Standard Notch

(The notch is 3 in. wide and has at its extremities a cut 1/8 in. long and 0.010 in. wide made with a jeweler's hack saw)

		Visible crack		Maximum load		Failure		
Spec. No.	Temperature, ° F.	Energy, in.-lb.	Load, lb.	Energy, in.-lb.	Load, lb.	Energy, in.-lb.	Load, lb.	Type of failure, % shear
Br-22-18	−12.7	3,900	234,200	36,700	293,000	36,700	293,000	1
Br-22-8	−10.3	6,700	249,300	31,500	283,500	31,500	280,000	0
Br-22-9	1.9	9,900	245,000	46,700	296,300	46,800	295,000	2
Br-22-11	2.0	4,800	240,800	92,600	332,500	92,600	328,000	6
Br-22-17	2.8	1,600	224,800	36,000	290,000	36,000	290,000	1
Br-22-10	11.6	10,100	240,500	140,300	340,100	335,100	74,500	100
Br-22-5	11.9	7,800	243,300	138,600	346,500	286,800	210,000	59
Br-22-2	12.1	10,500	239,500	34,300	279,500	34,300	279,500	0
Br-22-12	13.0	5,200	232,200	134,000	329,700	310,900	32,000	100
Br-22-7	13.6	6,300	237,300	30,000	280,500	30,000	280,500	1
Br-22-20	19.3	3,400	230,000	120,000	325,600	295,100	78,000	100
Br-22-19	19.6	3,500	230,000	120,000	329,300	306,500	40,000	100
Br-22-4	20.3	2,700	230,000	120,700	329,500	315,500	45,000	100
Br-22-3	30.0	1,000	224,500	129,200	329,500	316,300	35,000	100
Br-22-1	41.5	7,400	230,700	132,900	337,300	330,400	25,000	100
Br-22-6	68.8	6,500	228,500	140,200	327,000	350,800	30,000	100

sity of Illinois[2] data for energy to maximum load are shown in Table 10.

Figure 19 shows the maximum loads plotted as ordinates, Fig. 20 the energies to maximum load as ordinates and Fig. 21 the percent shear as ordinates with temperatures as abscissas in each case. University of Illinois[2] data are superimposed on the Swarthmore data in Fig. 20.

"E" STEEL

The behavior of the 16 specimens of E steel is quite erratic, although not to the degree found in C steel. It is interesting to note that only these two steels were characterized by "thumbnails" adjacent to the notch. These "thumbnails" are quite evident in Fig. 22 which shows the fracture surfaces of E steel. The formation of the "thumbnails" was accompanied by a sharp snap clearly audible to the test crew, together with an abrupt drop in load of 20,000 to 50,000 lb.

Specimen E-36-2, shown in Fig. 23, is of interest. To the test crew it seemed that the cleavage fracture occurred "instantaneously" over the entire cross section. Subsequent examination of the fracture surface showed the familiar "thumbnails" which may indicate that the crack front paused for a very small increment of time and then proceeded to complete failure.

Table 11 gives the Swarthmore data for E steel. University of Illinois[2] data for energy to maximum load are shown in Table 12. Figure 24 gives the maximum loads plotted as ordinates, Fig. 25 the energies to maximum load as ordinates with University of Illinois data superimposed, and Fig. 26 the per cent shear as ordinates with temperatures as the abscissas in each figure. By a comparison of the latter two figures with Figs. 7 and 8 for C steel, it appears that the C steel is somewhat more erratic than E steel in both its energy-absorbing and per cent shear characteristics.

Table 8—"Br" Steel, Tests of Specimens 12 In. Wide Made at University of California

Spec. No. *	Temp., ° F.	Energy to max. load, in.-lb.	Type of failure, % shear
B-7	(−35)-(−34)	21,000	0
B-9	(−7)-(−6)	36,000	0
B-1	32	112,000	83
B-6	50–51	114,000	100
B-3	70–73	115,000	94

* These are the designations of plates assigned by the University of California as described in their final report.[1]

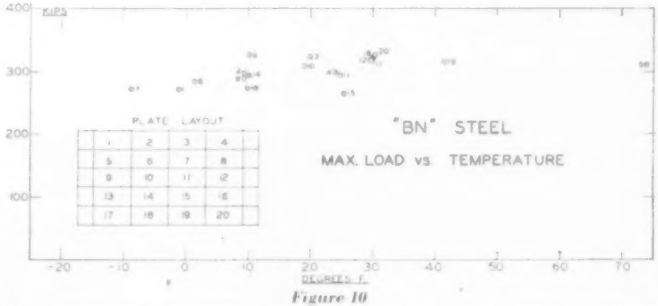

Figure 10

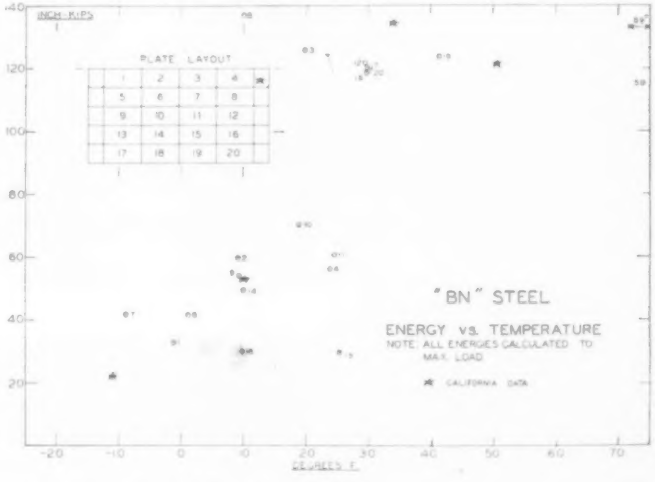

Figure 11 (Right)

Table 9—"Dn" Steel, Tests of Specimens 12 In. Wide, 3/4 In. Thick with Standard Notch

(The notch is 3 in. wide and has at its extremities a cut 1/8 in. long and 0.010 in. wide made with a jeweler's hack saw*)

		Visible crack		Maximum load		Failure		
Spec. No.	Temperature, °F.	Energy, in.-lb.	Load, lb.	Energy, in.-lb.	Load, lb.	Energy, in.-lb.	Load, lb.	Type of failure, % shear
Dn-33-5	−16 5	4900	255,500	27,700	285,400	27,700	285,400	0
Dn-33-9	−2 9	4800	248,200	31,500	291,000	31,500	291,000	0
Dn-33-1	−2 0	6400	260,400	36,900	306,000	36,900	306,000	0
Dn-33-19	4 8	4500	249,000	35,700	294,000	35,700	294,000	0
Dn-33-4	4 9	3400	238,000	54,700	324,000	54,700	324,000	1
Dn-33-10	9 6	6100	250,300	66,400	323,000	66,400	323,000	3
Dn-33-8	9 9	3600	245,000	130,700	349,200	214,100	313,000	34
Dn-33-2	10 1	4700	245,200	125,300	358,900	280,700	242,000	52
Dn-33-18	15 0	4500	245,700	44,200	321,000	44,200	321,000	1
Dn-33-16	16 0	3700	243,600	59,500	316,200	59,500	316,200	2
Dn-33-3	19 6	4500	245,700	127,400	348,800	310,800	30,000	100
Dn-33-11	19 8	4700	242,600	86,000	338,000	86,000	338,000	4
Dn-33-17	24 8	6500	259,500	135,400	345,700	311,800	78,000	87
Dn-33-20	24 9	2600	244,100	140,400	355,000	346,700	60,000	100
Dn-33-13	29 8	3900	249,000	129,700	344,400	324,600	90,000	100
Dn-33-12	29 9	6000	247,300	125,000	343,200	300,600	125,000	77
Dn-33-7	41 0	4400	241,500	117,500	340,500	314,900	40,000	100
Dn-33-14	55 4	7500	243,500	127,900	336,900	314,900	48,000	100
Dn-33-6	78 4	2900	230,000	119,900	332,500	316,400	60,000	100

GENERAL DISCUSSION

A. Types of Failure

Generally specimen fracture occurred in two extreme modes—cleavage and shear; however, the following sequences of fracture as fracture progressed from the notch were also observed in individual specimens: cleavage to shear, shear to cleavage cleavage to cleavage, cleavage-shear-cleavage and shear-cleavage-shear. The shear failures were of two types, one of which had a single surface and the other a double surface. Cleavage fractures exhibited a sparkling granulated surface while the shear fractures appeared dull.

Photographs of the grids of the specimens having the lowest and highest energy absorption tested at Swarthmore are shown in Figs. 27 and 28, respectively. Figure 29 depicts a cleavage-shear-cleavage fracture as exemplified by Specimen C-24-8.

The appearance of the fracture as based upon the per cent shear was estimated as follows: the sum of the lengths of shear tears on both sides of the notch was divided by the total length of fracture surface. It must be noted that the latter length is not always the 9 in. of net cross section since some ductile tears do not proceed straight across the specimen but make an angle to the transverse axis such as shown for Specimen Dn-33-20 in Fig. 28.

B. Specimen Behavior During Testing

A number of interesting observations were made of specimen behavior during the program. The first to be spoken of is the vibrational response of the steels, which was first noticed in the following manner. The electrical instrumentation for measuring elongation was composed of the conventional setup of SR-4 Bridge Balance Unit and Strain Indicator, and it was the latter which was used in setting

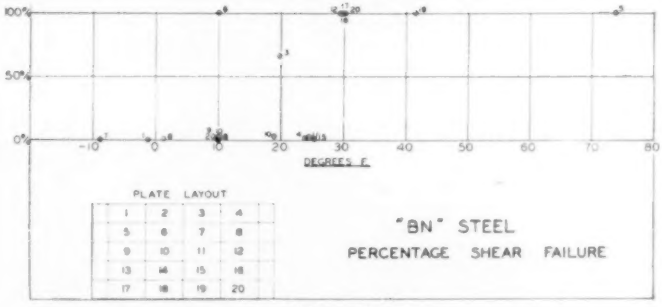

Figure 12

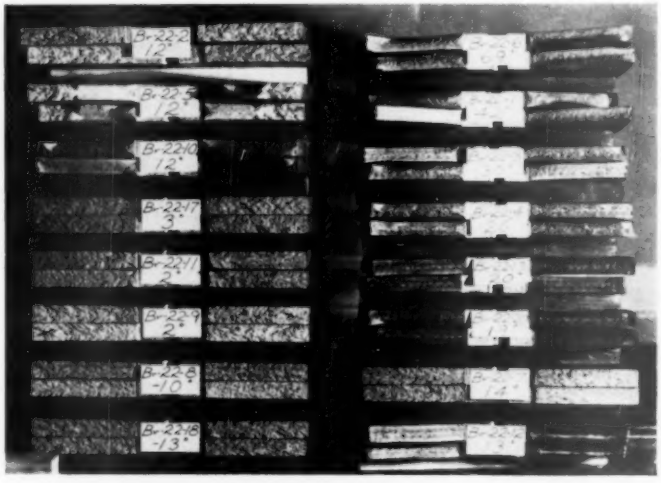

Fig. 13 "Br" steel, photograph of fracture surfaces

Fig. 14 Specimen Br-22-12, showing striations along fracture surfaces

points on the load-elongation curve, the load being taken as the dependent variable and the elongation as the independent variable. While loading a ductile specimen the needle of the Strain Indicator would rotate uniformly over the meter face. After a number of experiments had been run, it was definitely established that cleavage fracture of a specimen was almost always preceded by one of two different motions of the needle.

The first type consists of a "stepping" or jerking motion of the indicator needle, always in the same direction. In the second type, the needle progressed with an oscillatory motion of three or four cycles per second superimposed on the steady movement of the needle during increasing load. Such oscillation was intermittent in the early stages preceding cleavage fracture, but became continuous as the break was approached. The amplitude of this vibration is estimated to be of the order of 0.0005 in. over the 9-in. gage length.

In some specimens these motions stopped suddenly and such specimens ultimately failed by shear. It is considered very probable that the inertia of the moving parts of the galvanometer was sufficiently large to mask higher frequency components coming from the gage. The SR-4 gages were of the static type and hence the gages could also mask the response. The characteristic behavior described above was not found in those cleavage failures which occurred after a ductile maximum load had been passed.

The possibility was considered that the vibration might be magnetically induced in the gages by changes in the specimen. To check this, a coil of 1000 turns was mounted around the specimen, its leads being fed into an oscilloscope. No observable effects were indicated by this method even though the input condenser of the oscilloscope for some tests was shorted out to be certain that very low-frequency voltage changes were not being blocked. The conclusion of this approach was that the magnetic effects, if any, have such a low time rate of change that the voltage induced by

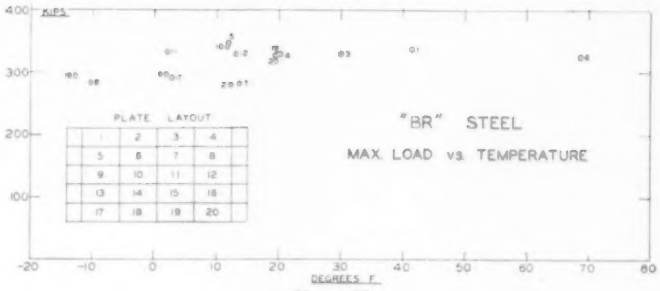

Figure 15

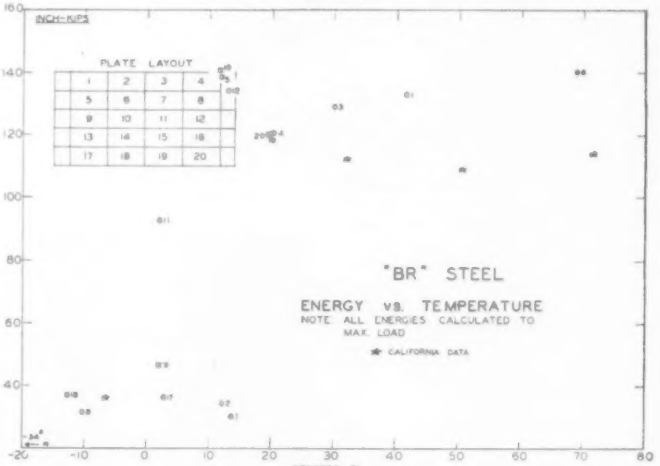

Figure 16

Table 10—"Dn" Steel, Tests of Specimens 12 In. Wide made ta University of Illinois*

*Spec. No.**	*Temp., ° F.*	*Energy to max. load, in.-lb.*	*Type of failure, % shear*
15-5A	41	100,000	87
9-2	30	109,000	80
15-6B	16	99,000	46
10A-4	1	36,300	0

* See page 12 of Reference 2.

Table 11—"E" Steel, Tests of Specimens 12 In. Wide, 3/4 In. Thick with Standard Notch

(The notch is 3 in. wide and has at its extremities a cut 1/8 in. long and 0.010 in. wide made with a jeweler's hack saw.)

		Visible crack		*First maximum*		*Second maximum*		*Failure*		*Type of failure % shear*
Spec. No.	*Temp., ° F.*	*Energy, in.-lb.*	*Load, lb.*	*Energy, in.-lb.*	*Load, lb.*	*Energy, in.-lb.*	*Load, lb.*	*Energy, in.-lb.*	*Load, lb.*	
E-36-7	61 3	3,900	229,800	21,400	262,500	...	...	21,400	262,500	1
E-36-2	61 9	2,300	226,500	27,600	256,700	...	...	27,600	256,700	0
E-36-19	70 2	4,000	225,300	27,000	254,400	39,700	242,000	39,700	242,000	2
E-36-8	70 5	6,100	229,000	60,600	261,000	...	...	84,900	102,000	38
E-36-1	82 2	6,200	229,000	39,000	271,500	78,800	257,000	181,800	45,000	73
E-36-10	83 3	5,000	227,500	34,500	265,700	84,000	266,000	182,400	15,000	76
E-36-11	91 6	11,800	233,600	38,900	271,000	83,500	264,300	176,200	58,000	77
E-36-9	91 6	5,700	230,000	104,900	320,500	...	...	246,900	45,000	100
E-36-20	99 8	3,500	220,500	34,400	264,500	83,400	284,800	196,200	60,000	90
E-36-3	99 8	4,900	224,500	32,800	264,500	86,800	283,000	195,300	30,000	85
E-36-17	106 6	4,500	219,000	101,500	319,900	...	...	248,400	60,000	100
E-36-12	111 6	6,900	225,500	87,100	314,000	...	...	239,200	25,000	100
E-36-6	115 0	9,000	224,000	103,800	316,500	...	...	242,200	30,000	100
E-36-18	115 6	2,700	221,500	100,800	320,000	...	...	251,000	50,000	100
E-36-4	126 0	4,500	220,600	106,300	313,700	...	...	238,200	60,000	100
E-36-5	149 1	5,000	222,500	93,400	322,800	...	...	237,500	25,000	100

them was too minute to investigate in such a manner.

The second observation of specimen behavior is what might be called delayed fracture. It is convenient to discuss this in terms of testing procedure, as follows: When the elongation readings at one load were completed, an additional load was applied until the next increment of elongation was reached, at which point the pump of the testing machine was cut off and the elongation and thermocouple readings taken. The whole cycle of pumping and reading usually required about two minutes with half a minute needed for reading the 12 elongations. With this in mind, it is interesting to note that 13 specimens (slightly over 10% of the total tested) failed by cleavage after the pump was cut off, at which time the load would be slowly falling. These specimens fractured shortly after the maximum load had been reached and at a load lower than the maximum by five to ten thousand pounds.

The third observation concerning specimen behavior may well be closely related to the above. This concerns those specimens which failed by cleavage while reloading the specimen after completing a set of readings, fracture taking place before the previous maximum load had been reached. The five specimens in this group were C-24-19, Bn-21-8, Bn-21-14, Br-22-9 and Dn-33-16. (See load-elongation curves, Figs. 43, 44, 46, 47 and 50 and Appendix II.)

The last consideration of specimen behavior is the "double maxima" observed for certain specimens of C and E steels. This effect can produce considerable discrepancies in the energy-to-maximum load. For example, Specimen E-36-10, Fig. 51, Appendix II, has a difference of only 300 lb. in the two peak loads; yet the energy to the second maximum load was almost $2^1/_2$ times the energy to the first maximum load. Although it is possible to make the energy vs. temperature plots take on a more desirable appearance by using one or the other value, the points in the energy-temperature plots have been plotted strictly in accordance with the numerically greater load.

C. *Transition Temperatures*

Criteria for transition temperature are varied and depend largely upon the person making the interpretation. Many experimenters believe in drawing the best curve through the energy (to maximum load) temperature data and using certain points on this curve to define the transition temperature. In this report we have avoided drawing energy-temperature curves, since the scatter and weighting of data will rule the type of curve.

At this time it appears that decisions relative to transition temperature can be realistically discussed only by considering the data for each steel separately. The transition temperatures are stated as a zone of temperature.

Table 12—"E" Steel, Tests of Specimens 12 In. Wide made at University of Illinois*

*Spec. No.**	*Temp., ° F.*	*Energy to max. load, in.-lb.*	*Type of failure, % shear*
18-9A	128	66,000	94
23-3B	109	60,000	87
13A-5B	74	40,000	0
13A-5A	40	17,000	0
20-2A	−73	10,000	0

* See page 12 of Reference 2.

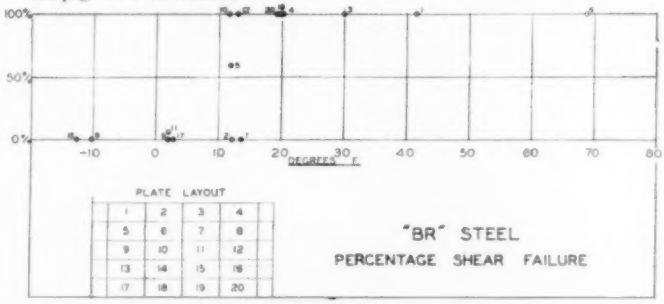

Figure 17

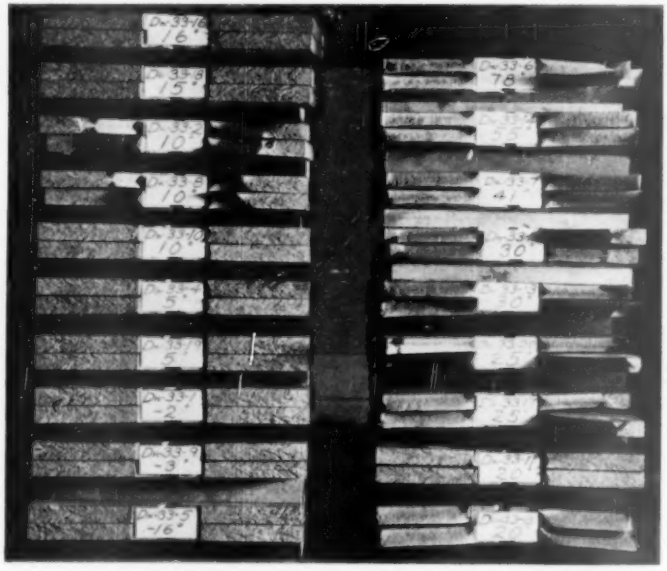

Fig. 18 "Dn" steel, photograph of fracture surfaces

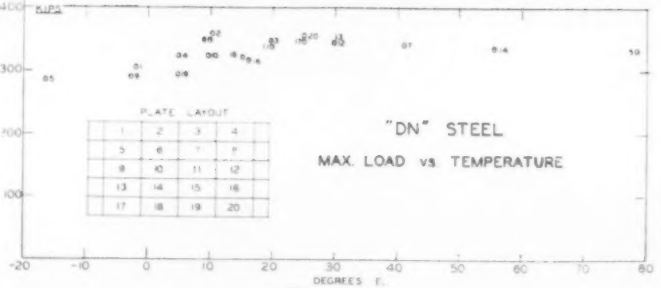

Figure 19

A Steel. Fractures with a low energy absorption occurred at a temperature as high as 58° F. High energy levels were observed for temperatures down to 42° F. The transition temperature for A steel on the basis of these data has been judged to be in a zone between 42 and 58° F. (See Fig. 3.)

The transition temperature zone based on appearance of the fracture as evaluated in terms of the per cent of shear also lies between 42 and 58° F. (See Fig. 4.)

C Steel. Fractures with a low energy absorption occurred at a temperature as high as 90° F. and a high level of energy absorption prevailed for temperatures down to 98° F. if Test 8 is omitted. Hence these data would place the transition temperature of C steel in a zone from 90 to 98° F. (See Fig. 7.)

The transition temperature zone based on appearance of the fracture as evaluated in terms of the per cent of shear lies between 90 and 116° F. (See Fig. 8.)

Bn Steel. Neglecting specimens 3 and 6 because Specimen 3 is overweighted by specimens 4, 10, 11 and 15 and Specimen 6 is overweighted by specimens 2, 9, 14 and 18, the transition temperature appears to be in a zone between 25 to 30° F. (See Fig. 11.)

The transition temperature zone based on appearance of the fracture as evaluated in terms of the per cent of shear also lies between 25 and 30° F. (See Fig. 12.)

Br Steel. Omitting Specimen 11, the transition temperature for this steel based on the energy to maximum load appears to be about 12° F.; however it is thought that a zone ranging from 10 to 15° F. is more likely. (See Fig. 16.)

The transition temperature zone based on appearance of the fracture as evaluated in terms of the per cent of shear also lies between 10 and 15° F. (See Fig. 17.)

Dn Steel. From the energy data, high energy absorption occurs for a temperature as low as 10° F., and low energy absorption occurs for a temperature as high as 16° F. Hence the transition temperature zone has been interpreted as being between 10 and 16° F. (See Fig. 20.)

The transition temperature zone based on appearance of the fracture as evaluated in terms of the per cent of shear lies between 15 and 25° F. (See Fig. 21.)

E Steel. On the basis of energy data, the high level of energy is judged to have a lower temperature limit at 92° F. which also marks the upper temperature limit at which low energy absorption occurred. The lower limit of the transition zone has been deemed to be at about 70° F. Hence the transition temperature has been estimated to lie in a zone between 70 and 92° F. (See Fig. 25.)

The transition temperature zone based on appearance of the fracture as evaluated in terms of the per cent of shear appears to lie between 70 and 100° F. (See Fig. 26.)

The above findings with reference to

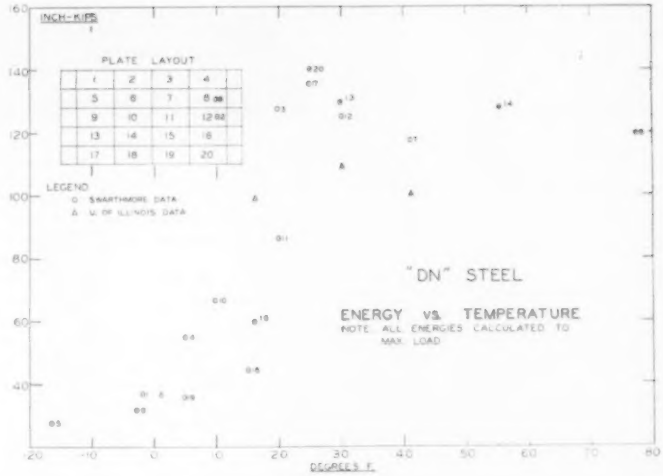

Figure 20

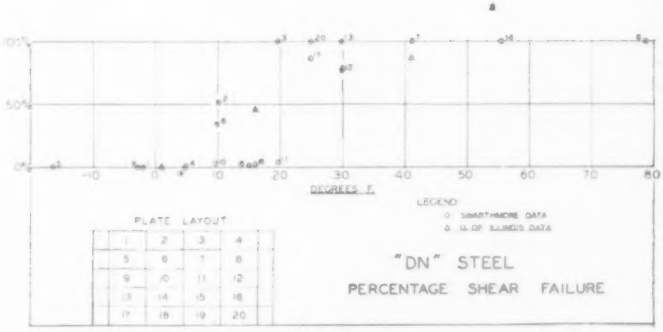

Figure 21

Fig. 22 "E" steel, photograph of fracture surfaces

transition temperature are summarized in the following Table 13.

Table 13—Summary of Transition Temperature Zones

Steel	*Based on energy absorption to maximum load, ° F.*	*Based on percentage of shear, ° F.*
A	42–58	42–58
C	90–98	90–116
Bn	25–30	25–30
Br	10–15	10–15
Dn	10–16	15–25
E	70–92	70–100

The mechanism by which steel either fails in the cleavage or shear mode is not clearly understood. If identical homogeneous steel specimens were subjected to carefully controlled tests it might be expected that the transition from shear to cleavage fracture would occur at a single temperature rather than in a temperature zone. Physical discontinuities are usually accompanied by sharp breaks in performance characteristics. The Br steel illustrates the point in question, test specimens 5, 10 and 12 exhibiting shear failure, while specimens 2 and 7 indicate cleavage failure, when all of these specimens were tested at approximately the same temperature.

D. Effect of Temperature on Maximum Load

In making a comparison of maximum loads it must be realized that for a cleavage failure the fracture load is usually the maximum load, while the maximum load for a ductile specimen is not the fracture load. In general the average maximum load is approximately 50,000 lb. lower in the cleavage mode than in the shear mode.

A summary of average maximum loads for those specimens failing in the completely shear or completely cleavage modes for the various steels is shown in the Table 14.

E. Comparison of Energy to Maximum Load

The average energies to maximum load for the various steels for specimens which broke by shear and by cleavage are shown in Table 15.

It can be noted by comparing the ratios of "shear" to "cleavage" energy in Table 15 with the ratio of shear to cleavage loads in Table 14, that the ratios of load are more consistent.

The high ratio of energy in the shear mode to energy in the cleavage mode for steels A and Br may possibly be explained by the presence of laminations in the A steel and the striations in the Br steel.

An additional complication in comparing energy arises from the occurrence of two peak loads while straining the speci-

Fig. 23 Specimen E-36-2, showing thumbnails which developed during complete fracture

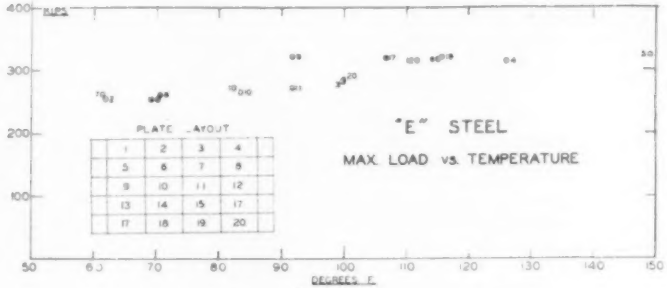

Figure 24

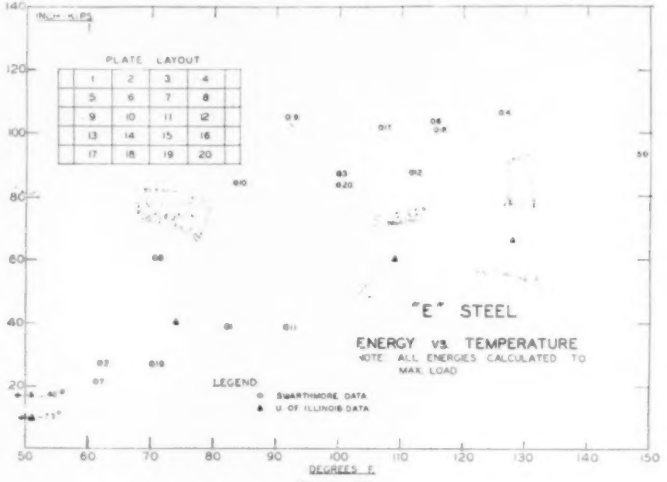

Figure 25

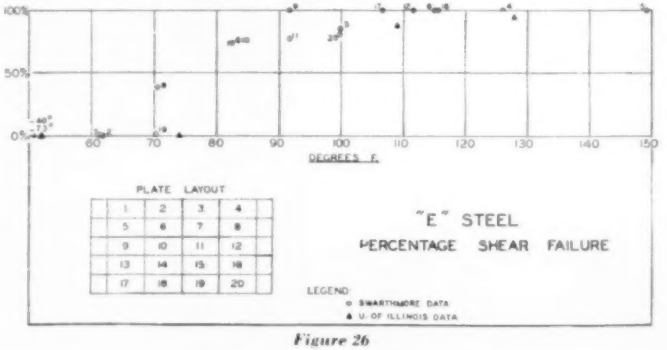

Figure 26

men, of which the first or the second load may be the greater. This is common for steels C and E and is shown for example in Figs. 48, and 51.

F. Variations Due to Location of Specimen in a 6- x 10-Ft. Plate

The tests were planned so that differences due to location of specimens within a 6- x 10-ft. plate could be studied. It was desired to compare the specimens taken from the outer longitudinal zones of a rolled plate with specimens from the center zones of the plate, as well as comparing specimens taken from the same longitudinal zone in the direction of rolling.

The results do not enable any general statements to be made relative to the effect of longitudinal or transverse position of the specimen within the plate. It appears, however, that local variations or inhomogeneities in a plate are likely to have more effect than normal metallurgical and rolling variations within the plate.

As an example of differences in energy absorption, see Fig. 16 and note that specimens 9, 11 and 17 of the Br steel were all tested at approximately 2° F. A comparison of Specimen 9 from the center zone and Specimen 17 from the outside zone shows less energy variation between these specimens than shown by specimens 9 and 11 taken from the center zone. On the same figure also note the great differences between specimens 5 and 7 which were taken from the same longitudinal strip. When a small number of specimens exist, a comparison of outside and center specimens is meaningless unless specimens lying in the same longitudinal zone behave consistently alike at a given temperature. Cases of agreement may be noted by comparing specimens 19 and 20, and 10 and 12 on Fig. 16. A careful study of all steels shows no consistent performance.

Fig. 27 Specimen A-18-13, lowest energy absorption to maximum load of all specimens tested

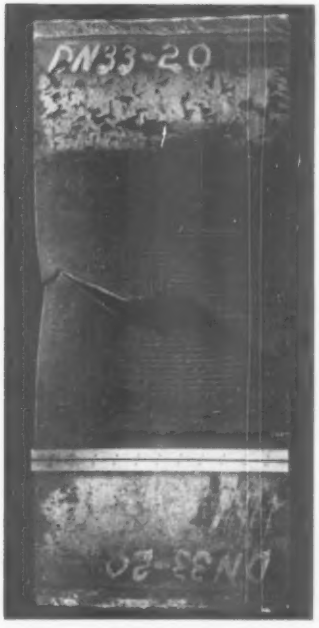

Fig. 28 Specimen Dn-33-20, highest energy absorption to maximum load of all specimens tested

G. Tensile Tests

The yield point and tensile strength of the various steels were determined by using one 6-in. wide, 48-in. long and ¾-in. thick unnotched specimen of each steel. The results are tabulated below.

Steel	*Yield point, psi.*	*Tensile strength, psi.*
A	31,400	59,500
C	37,400	67,800
Bn	32,100	59,300
Br	32,200	57,700
Dn	34,300	61,300
E	33,200	59,200

The above values, when compared with transition temperatures, show no relationship between strength and transition temperatures. The average maximum loads tabulated in Table 14 bear a closer relationship to the tensile strength but even here a strict correlation is not achieved.

The comparison of average energy for ductile behavior with tensile strength shows that Br steel, having the highest average energy absorption, has the lowest tensile strength.

H. Future Analysis of the Data

The recorded data may be analyzed and interpreted in various ways. Since the same facts may be seen from different points of view, consequences stemming from a given point of view are left for consideration separately from the facts themselves, and will be the subject of further analysis.

As an *index of ductility* use has been made of the energy absorbed by the specimen, taken up to the point of the maximum load on the load-elongation curve.

Table 14

Steel	*Column 1, average max. load in lb., specimens failing in 100% shear*	*Column 2, average max. load in lb., specimens failing in 0% shear*	*Ratio of column 1 to column 2*
A	317,000	268,000	1.18
C	348,000	294,000	1.18
Bn	319,000	286,000	1.11
Br	333,000	288,000	1.16
Dn	346,000	311,000	1.11
E	318,000	264,000	1.20

Table 15

Steel	*Column 1, average energy to max. load for specimens failing in 100% shear, in.-lb.*	*Column 2, average energy to max. load for specimens failing in 0% shear, in.-lb.*	*Ratio of column 1 to column 2*
A	95,700	25,500	3.75
C	105,900	38,400	2.74
Bn	122,000	47,800	2.56
Br	131,000	34,300	3.80
Dn	128,900	49,200	2.60
E	99,830	32,000	3.12

Fig. 29 Specimen C-24-8, example of cleavage-shear-cleavage mode of fracture

In ductile specimens this point is not well defined, since the curve there is quite flat. Such a curve is given in the report for each specimen and the limit to which the energy value is taken may be chosen by a reader in *any way* desired. The limits used in the analysis of this report are indicated on the curves.

This choice for the index of ductility was made partly because it has been used in earlier work, but also partly because it is less subject to doubt as to its exact value than the other index which might be used, namely, the energy to fracture. It is recognized that in some design problems energy to fracture may be the significant quantity.

As an index, a value of energy may be preferred to deformation, or to an estimate based on appearance of fracture, because energy is itself pertinent in design and not simply an indicator whose validity must be established by some process of correlation.[4]

The threshold of brittleness also may be chosen in different ways. At a sufficiently high temperature no risk of brittleness exists, but as temperature is reduced, a temperature is reached at which this is no longer true. At lower and lower temperatures the chance of brittle action becomes greater and greater. No need is felt to follow this development to the point where the chance approaches certainly of brittleness, since material certain to act in a brittle mode is useless for structural applications.

However a limit must be set for what is acceptable. For convenience in the work of several laboratories the threshold has been put at the temperature at which the index of ductility has fallen to half its value at the upper level. This does not at all mean that a 50-50 chance of brittle fracture is acceptable in service structures; it leaves the whole question of the prediction of the threshold in service from laboratory tests on a relative basis. The ground for this choice is that the half-level threshold is easier to determine than the more indefinite limit at which the sloping line of transition levels off at the fully ductile value of the index.

Wherever possible, it is preferred to place the threshold at the beginning of transition, the temperature below which ductile behavior is no longer assured.

The reason for this choice is as follows: placing the threshold at half-value of the index overestimates the security in the case of a material whose transition zone covers a wide range of temperatures, or whose transition line slopes moderately and not steeply.

In addition, however, another margin of security must also be provided even if the criterion places the threshold at the point of departure from the upper level, since this point is in itself uncertain. The question is how far above the threshold must we stay to be *sure* of not going below it.

An analysis by which a line may be fitted to transitional data, and at the same time the tolerance of the threshold measured, has been described in Reference 5. An analysis of the data in the present report will be made according to the scheme there described and will be separately reported.

CONCLUSIONS

1. The tentative transition temperature zones as found for the various steels is reported as follows, as based on two criteria:

Summary of Transition Temperature Zones

Steel	*Based on energy absorption, ° F.*	*Based on percentage of shear, ° F.*
A	42–58	42–58
C	90–98	90–116
Bn	25–30	25–30
Br	10–15	10–15
Dn	10–16	15–25
E	70–92	70–100

2. The ratio of the average maximum loads for specimens failing in 100% shear to the maximum loads for specimens failing in 0% shear was found to be practically constant for all steels tested.

3. The ratio of the average energy for specimens failing in 100% shear to the average energy for specimens failing in 0% shear is variable for the separate steels. A comparison between Bn and Br indicates a higher ratio for Bn. This may be due to normalizing.

4. The tensile tests of unnotched specimens indicate no correlation between tensile strength and the transition temperature, energy absorbed or maximum loads for the notched specimens.

5. The vibrational phenomenon observed in measuring strains for specimens that were later to prove brittle is worthy of further experimental investigation. This may lead to a clue regarding the physical changes prior to cleavage failure.

ORGANIZATION

The investigations were conducted at Swarthmore College in the Structural Engineering Laboratory. The late Scott B. Lilly, Chairman of the Division of Engineering, was the Technical Representative for the Project, and the work was performed under his general direction.

Samuel T. Carpenter, Professor of Civil Engineering, and Norris Barr, Research Associate in Engineering, have been in charge of the technical phases of the investigation. Captain W. P. Roop, U.S.N. (ret.), has acted as a technical consultant and has given invaluable assistance.

To a large degree, the success of the instrumentation of this project has been due to the efforts of Ewald Kasten, Mechanician. In addition, Mr. Kasten has directed the shop work, which has been done by the following staff: Theodore Bartholomew, Lawrence Robbins, Arnold Bleiman, Walter Cosinuke, Richard M. Turner and Robert Vernon.

Adolph Zell has served as a general technician on this project and has assisted in taking all data. John O. Briggs and Erwin Newman have made the drawings. Frances Shero and Ruth Sommer have assisted greatly in the preparation of the manuscript. Clifford Renshaw, Jr., and Steve Mucha have acted as photographers.

Dr. Finn Jonassen, of the National Research Council, has been a constant adviser.

Appendix I

INSTRUMENTATION AND PREPARATION OF SPECIMENS

Notching of Plates

The notch was located in the middle of the plate, and a jeweler's hack saw, 0.010 in. thick, was used for the last $^1/_8$ in. of the notch so that the acuity obtained would be comparable with that used by other laboratories that had tested these steels. Figure 30 shows the detail

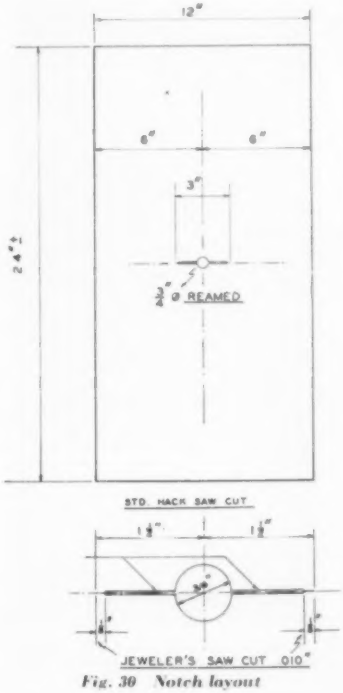

Fig. 30 Notch layout

of the notch and layout of the specimen. The edges of the plates were machined. A jig saw was mounted on a base as shown in Figs. 31 and 32 so that the saw could be moved at right angles to the axis of the piece. The depth of the saw cut could be easily controlled. Either a standard hack saw or a jeweler's hack saw can be used in the jig saw. Using this machine, notches were obtained that are similar and at ring angles to the axis of the piece.

Measuring Elongations Through the Elastic and Plastic Range

The problem was to design a gage which would permit the accurate measurement of elongations through the elastic and plastic range up to the point of failure. The requirement for the mounting was that the gage should not in any way be damaged by a cleavage failure. These conditions were met by mounting SR-4 gages on both sides of a flat spring, $10^1/_2$ in. long, mounted in ball bearing supports at the 9-in. gage lines. (See Figs. 33 and 34.) The first SR-4 gages were affected by moisture; therefore, bakelite SR-4 gages are now used. These instruments are made up of four main parts:

(*a*) Gage mountings: The mountings are centered by drilling holes $^1/_{16}$ in. in diameter and $^1/_{16}$ in. deep on the 9-in gage line at the proper distances from the edge of the plate. The hardened steel pins which are inserted in these holes are a part of the base piece which is $^5/_8$ in. in diameter. This wide support insures stability. Since the width of the test specimens narrows and a given transverse plane of plate may rotate, a ball bearing is provided to permit the rotation of the mounting about the $^1/_{16}$ in. center. The slot in which the end pivots of the gage are inserted will then remain perpendicular to the axis of the piece throughout the test. The pins of each end of the flat sping permit the flat spring to rotate freely at the ends.

(*b*) The second part is the flat spring with the bakelite SR-4 gages baked on.

(*c*) The third part is a frame for retaining the end gage mountings in position. The frame surrounds the test

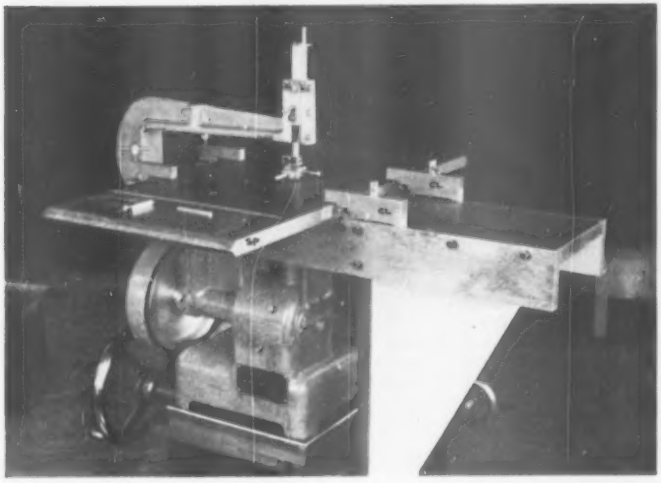

Fig. 31 Jig saw assembly

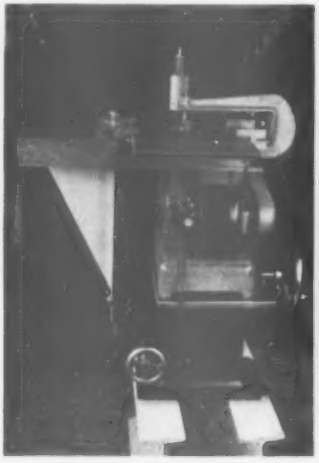

Fig. 32 Jig saw assembly

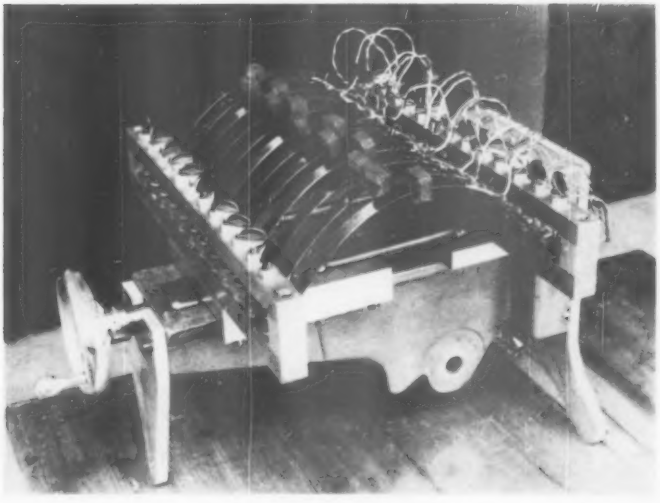

Fig. 33 Gages in calibrator

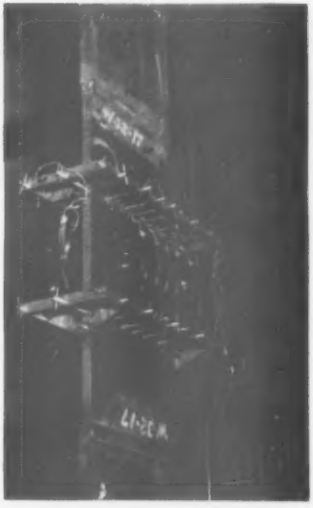

Fig. 34 Gage assembly

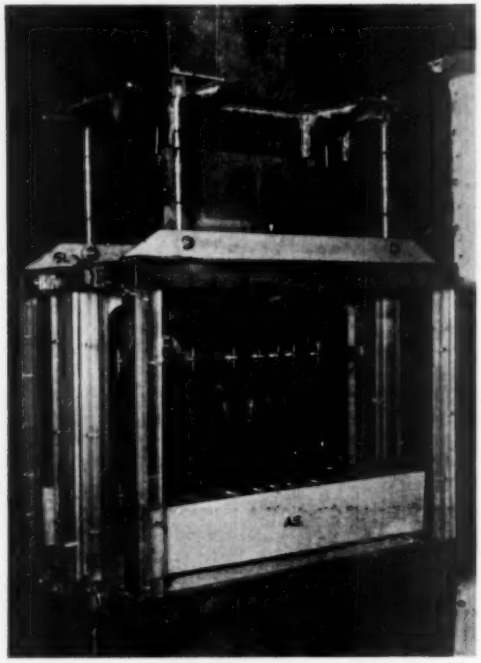

Fig. 35 Plexiglas chamber

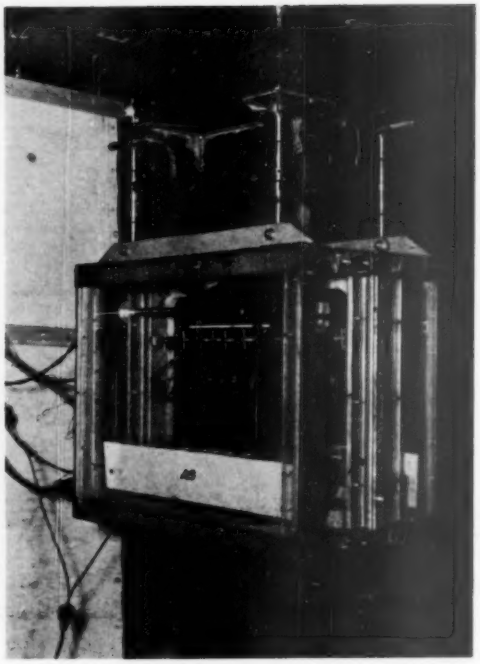

Fig. 36 Plexiglas chamber

piece and is held in position by firm but unrestrained attachments to the specimen outside of the gage length.

(*d*) The fourth part consists of a coil spring which is sprung between the retention frame and the gage mounting. These springs hold the mountings in close contact with the member but are flexible so that any differential change in length between the points where the gages are mounted and the points on the specimen to which the retention frame is attached will be accommodated by the movement of the spring.

These gages have proved entirely satisfactory in service and even with cleavage fracture the gages often remain in position after the break.

Temperature Control Chamber

The tests necessitated raising the temperature above room temperature and lowering it to points well below room temperature. A double-walled temperature-control chamber of Plexiglas was built to permit visual observation. The halftones, Figs. 35 and 36, show clearly the method of supporting the chamber on the test specimen. The chamber is composed of two separate boxes held against the test piece by adjustable clips. The edges of the boxes are equipped with sponge rubber which rests against a wooden member the thickness of the test plate, so that the chamber so formed can be adapted to the testing of specimens of any thickness. In the photograph, the heating elements are shown together with fans for circulating the air.

Description of Cooling System

The cooling system may be considered under three subheadings: (*a*) Source of low temperature; (*b*) measurement of temperature; (*c*) control of temperature. The source of low temperature was dry ice placed in a double-walled box insulated with fiber glass and marked *A* in Fig. 37. It is supported on cantilever brackets projecting from the movable platform and has a capacity of 250 lb. of dry ice.

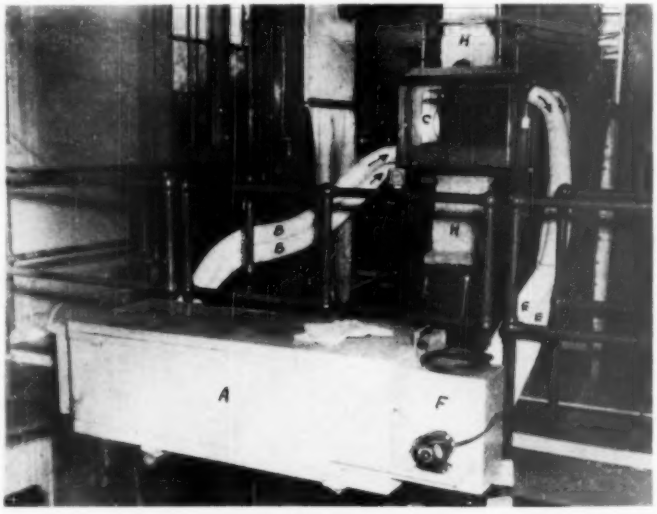

Fig. 37 Cooling mechanism

The air passes from Box A into a mixing chamber from which two separate flexible insulated ducts marked *B* carry the cooled air, one to each half of the temperature-control chamber made of Plexiglas and marked C.

In the bottom of either half of the control chamber is a diffuser *D*, having many small holes. After passing through the control chamber, the air is conducted through insulated ducts marked *E*, similar to the ducts marked *B*, to an insulated box containing a centrifugal blower marked *F*, driven by the motor shown in Fig. 37. Between the fan chamber and the dry-ice box the slide valve *G* is inserted. This valve is operated manually by raising or lowering the slide.

To determine the temperature of the specimen, thermocouples are located at three points on the specimen: (1) in the $^1/_4$-in. drill hole; (2) at a point just above the 0.010-in. notch in the specimen; (3) $5^1/_2$ in. above the center of the notch. The fourth thermocouple measures the temperature of the air. The potentiometer for these measurements is shown at *J* and the galvanometer at *K* in Fig. 37.

The ends of the test specimen are covered with sheets of cellular rubber as at *H*, and insulating shims are placed between the grips and the spacers of the upper and lower crossheads. The ducts carrying the cold air to the Plexiglas chamber are insulated by wrapping fiber glass around the tubes and covering them with muslin. This muslin has been coated with asphalt paint to prevent the moisture from entering the insulation.

This method has proved satisfactory; the temperature differential between the gage at the 0.010-in. notch and that $5^1/_2$ in. above the center of the notch was 1.5° for specimen tested at 17°. For specimen tested at 62° F. the differential between these points was 0.1° F.

Accessories Are Mounted on Elevator

The elevator attached to the columns supplies sufficient area so that all of the electrical apparatus used in connection with the gage assembly and also the cooling box, with the necessary blowers, can be mounted near the specimen.

Appendix II

NOTES ON LOAD-ELONGATION CURVES

It may be noted that some temperatures shown on the load-elongation curves are indicated to 1° F. and others to $^1/_{10}$° F. This is due to the fact that more

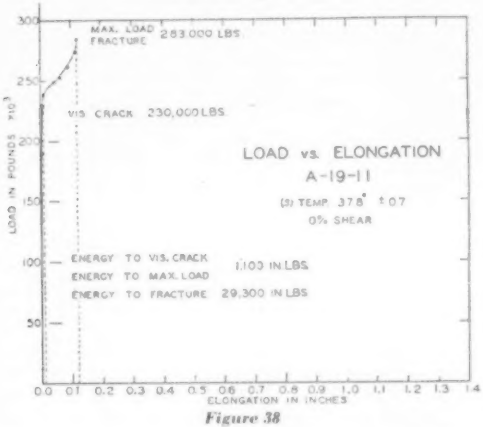

Figure 38

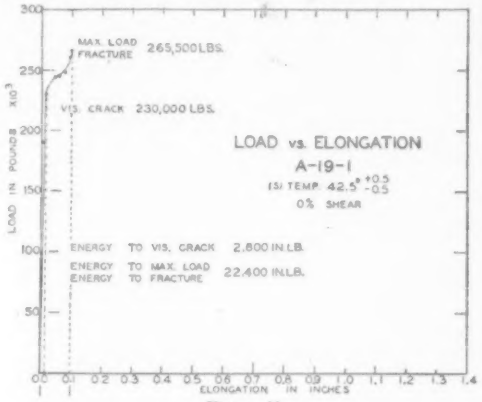

Figure 40

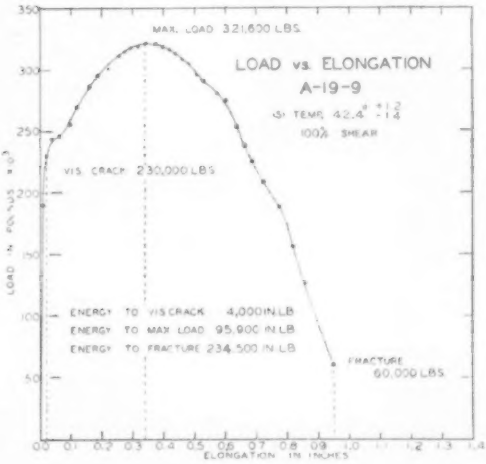

Figure 39

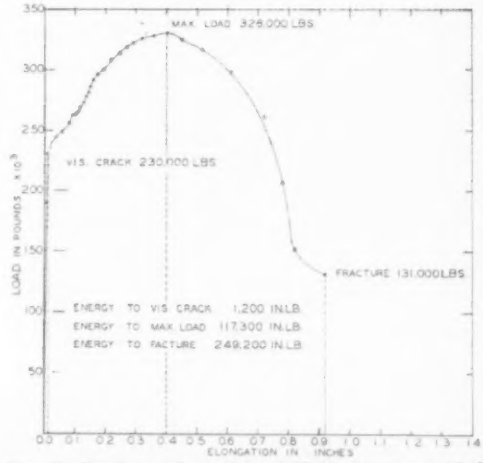
MAX. LOAD 329,000 LBS.
VIS. CRACK 230,000 LBS.
FRACTURE 131,000 LBS.
ENERGY TO VIS. CRACK 1,200 IN.LB.
ENERGY TO MAX. LOAD 117,300 IN.LB.
ENERGY TO FACTURE 249,200 IN.LB.
LOAD IN POUNDS X10³
ELONGATION IN INCHES

Fig. 41 Load vs. elongation, A-19-12, (3) temp. 46.4° $^{+2.6}_{-0.8}$, 100% shear

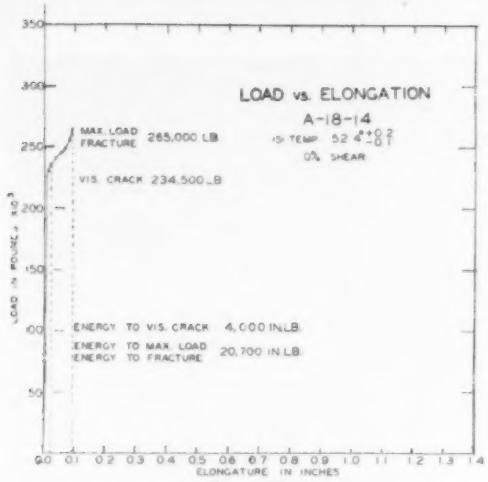

Figure 42

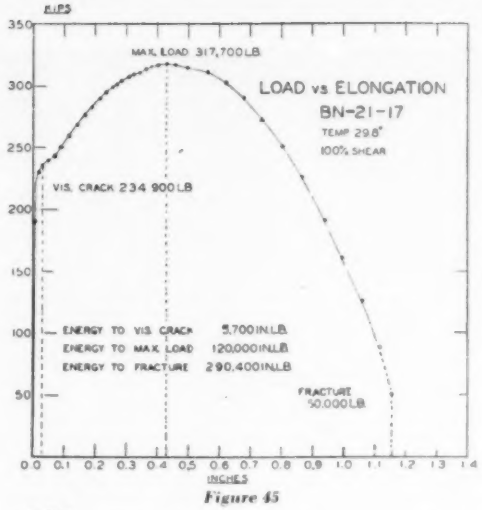

Figure 45

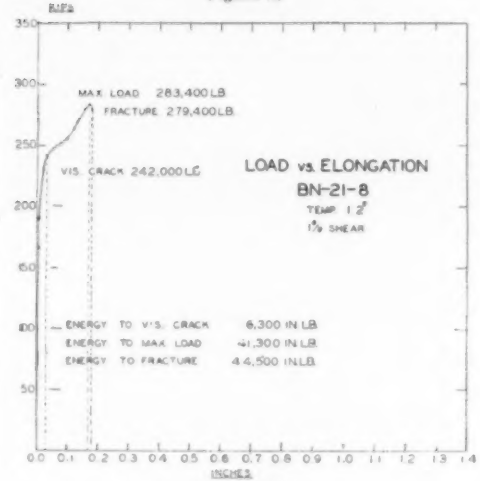

Figure 43

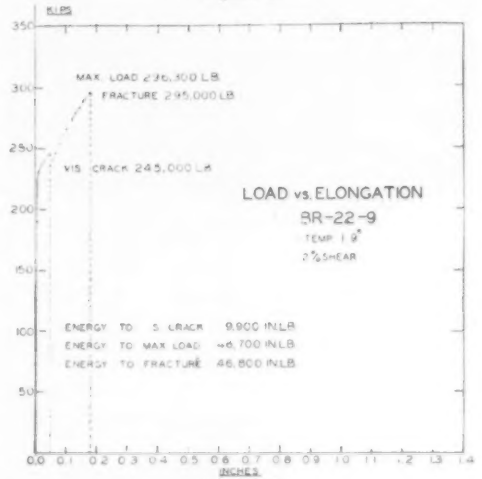

Figure 46

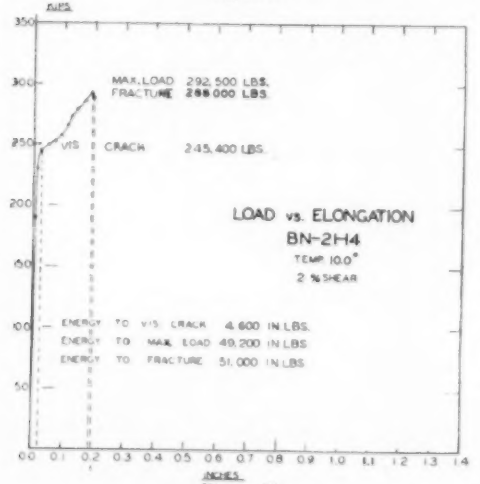

Figure 44

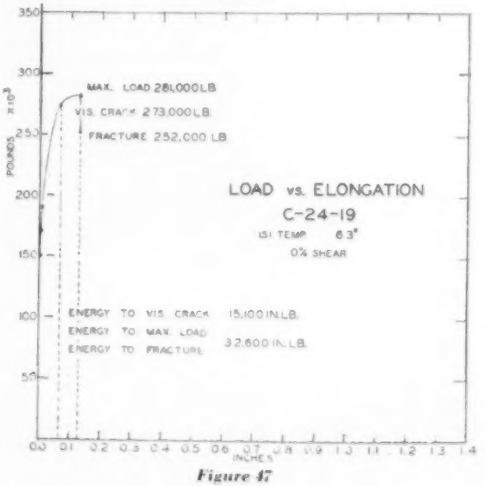

Figure 47

precise temperature-measuring equipment was available for the latter tests. For tests run with this instrumentation the average temperature at the $^3/_4$-in. drill hole is given together with its variation during the test.

An observation concerning the shape of the load-elongation curve may also be made. In the first tests run it was considered sufficient to take readings and plot values of elongation of the order of 0.05 in. over a gage length of 9 in. While this does not alter the energy values significantly, it does tend to obscure some of the finer details of specimen behavior. In view of this, the testing procedure was altered to record and plot more points along the load-elongation curve. As a result a rather characteristic shape of the curve preceding cleavage fracture has been noticed; i.e., a rapidly increasing slope as the material begins to behave in a brittle fashion. Examples of this are to be seen for the following tests: Fig. 38, A-19-11; Fig. 40, A-19-1; Fig. 42 A-18-14; Fig. 48, C-24-15.

However, this type of response is not exclusively associated with cleavage fracture since it also is evident in ductile specimens such as Fig. 41, A-19-12, and Fig. 49, C-24-3.

It is also brought to the reader's attention that a dashed portion near the end of the load-elongation curve indicates either an estimated fracture load or estimated fracture elongation, or both. In a few tests one-half of the specimen failed before the other. When this occurred the load-elongation curve was terminated at the last load at which both sides were still intact.

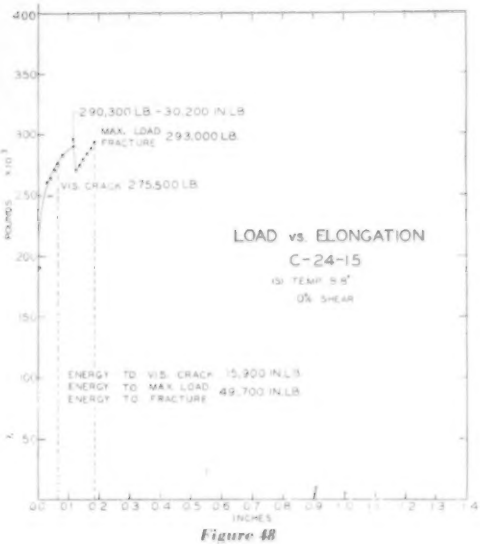

Figure 48

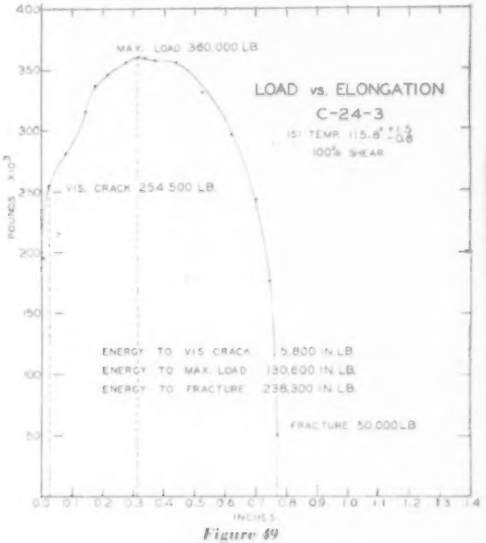

Figure 49

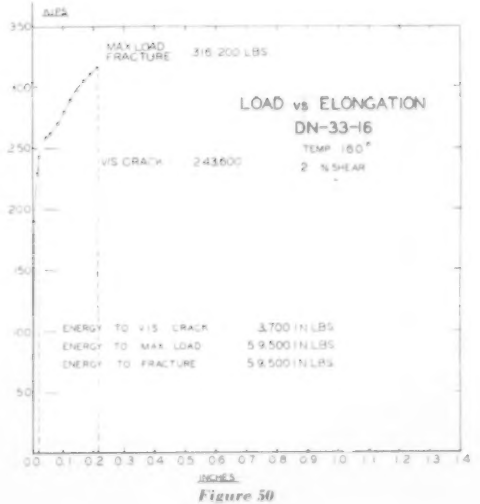

Figure 50

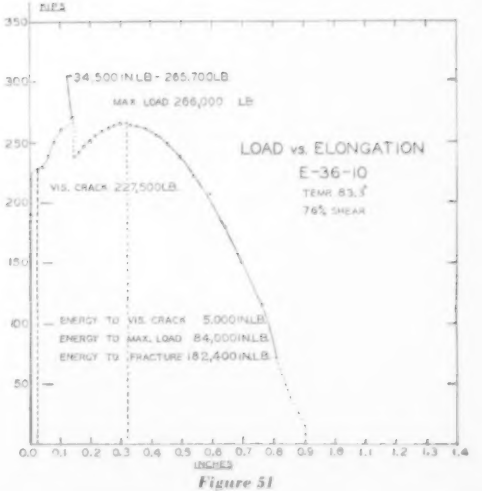

Figure 51

Part II

INTRODUCTION

Research on notched flat plate test specimens has raised a number of questions, especially concerning the effects of geometry and metallurgy on the energy absorbed by the specimen. The segregation of these two classes of influences has become a primary objective.

To study some of these pertinent factors, a series of tests has been made in which thickness (as-rolled) varied from $^1/_2$ to $1^1/_2$ in. and width varied from 2 to 10 in. The steel was all obtained from one heat, semikilled practice, with the following chemistry: Carbon, 0.16%; Manganese, 0.93%; Suphur, 0.034%; Silicon, 0.020%.

An orderly program of tests was laid out with reference to the sectional aspect ratio—defined as the width divided by the thickness of the plate. The notches are transverse slots at mid-width, of length equal to $^1/_4$ width of the plate. These terminated in drilled holes of diameter equal to $^1/_{16}$ the thickness. These details are shown on Fig. 52. For a given aspect ratio, specimens in all thicknesses are geometrically similar to each other.

TEST PROGRAM

The schedule of aspect ratios is outlined in Fig. 53; the present paper deals only with a limited number of tests from this total program.

In cutting specimens from the plates special attention was given to their position with reference to the distance from the edges of the rolled plate. The quantity of steel available was not very great and careful layout was necessary. The layouts used are shown in Figs. 54, 55, 56 and 57, made with the help of Miss Sandomire.

TEST PROCEDURE

The longitudinal elongations were measured on a gage length equal to $^1/_4$ width; the clip gages previously used on 9-in. gage length were adapted to other gage lengths. In the course of a test, temperature was first set and stabilized and then load was increased in steps at each of which elongations were read. Special note was made of the appearance of a visible crack in the notch, after which the test was continued, either to the point of fracture on a rising load, or, in case of ductile behavior, through a maximum to fracture on a diminishing load. Typical load-elongation diagrams are shown in Fig. 58. The area under the curve taken to maximum load, whether in brittle or ductile fracture, is designated *E1*. In a brittle specimen this is the total value. In a ductile specimen, total energy absorbed to fracture is designated *E2*. Thus *E2* − *E1* is the energy required to propagate the ductile fracture after passing maximum load. In addition, the fracture surface was examined and the fracture surface was examined and the fraction showing characteristics of shear action recorded.

TEST RESULTS

Data obtained from plates of $^1/_2$ in. thickness are shown in Table 16. Data for other thicknesses are too incomplete to be reported now.

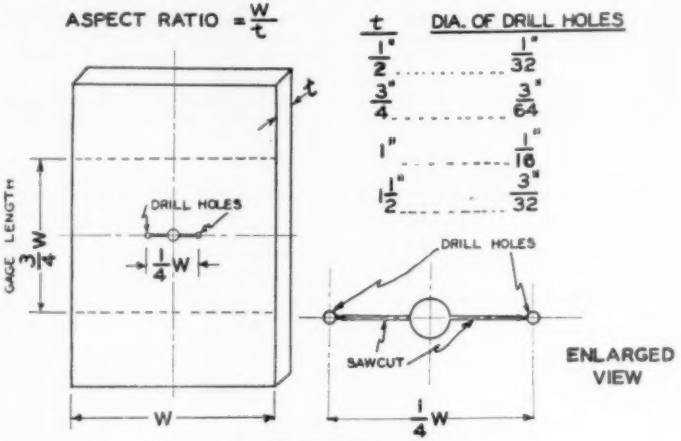

Fig. 52 Typical specimen

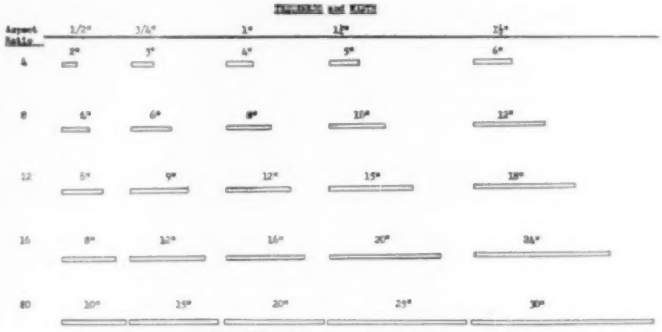

Fig. 53 Aspect ratio program

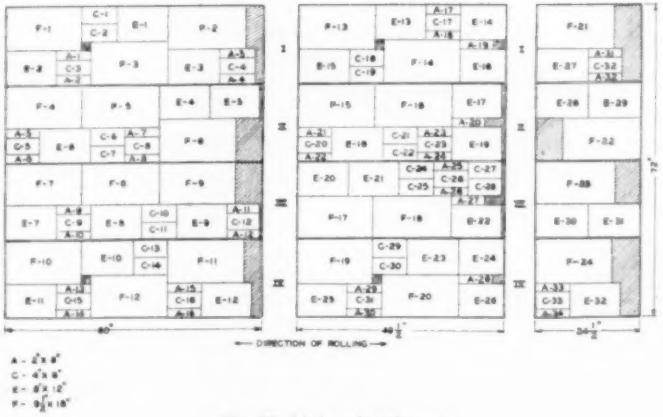

Fig. 54 $^1/_2$-in. plate layout

Table 16

Plate, Thickness ½ inch

Block No.	Spec. No.	Temp., °F.	To visible crack: Energy, in.-lb.	To visible crack: Load, lb.	To maximum load: Energy E1, in.-lb.	To maximum load: Load, lb.	To fracture: Energy E2, in.-lb.	To fracture: Load, lb.	Energy difference, E2 − E1, in.-lb.	Shear, %
Aspect Ratio, 4										
I	A-1	−18	3,200	48,300	6,500	53,300	8,500	50,000	2,000	8
	A-2	−10	3,000	47,200	6,500	53,800	7,350	53,600	850	0
	A-3	0	2,740	46,500	6,400	52,000	14,300	14,000	7,900	100
	A-4	−20	3,250	47,300	6,350	53,600	11,600	41,000	5,250	30
	A-31	−20	3,500	49,000	6,300	53,200	6,300	53,200	0	0
	A-32	−10	3,200	47,500	6,750	52,900	14,700	17,000	7,950	100
	A-17	−20	2,700	46,500	6,350	53,000	13,800	17,000	7,450	100
	A-18	−64	3,850	48,200	7,850	54,000	7,850	54,000	0	0
II	A-5	0	1,690	42,200	6,060	51,600	13,370	13,000	7,310	100
	A-6	−32	1,760	42,800	6,760	53,700	13,680	13,000	69,20	100
	A-7	−52	1,960	42,500	6,870	54,700	6,870	54,700	0	0
	A-24	−49	1,850	42,600	7,350	54,400	7,350	54,400	0	0
	A-23	−35	2,100	42,000	7,250	53,500	7,250	53,300	0	0
	A-22	−25	1,990	42,800	6,800	53,200	14,200	15,000	7,400	100
III	A-9	0	1,300	43,200	6,350	53,900	12,300	13,000	5,950	100
	A-12	−40	2,200	44,200	6,200	54,400	6,200	54,400	0	0
	A-25	−25	2,400	44,900	7,300	54,500	15,100	13,000	7,800	100
	A-10	−35	1,950	43,500	7,500	55,000	14,400	16,000	6,900	100
	A-26	−40	2,500	44,100	6,800	54,100	6,800	54,100	0	0
	A-11	−35	2,100	44,500	6,200	53,500	6,200	53,500	0	0
IV	A-13	0	2,800	45,500	5,850	51,800	14,300	12,000	8,450	100
	A-14	−20	3,350	47,500	7,200	53,100	16,950	13,000	9,750	100
	A-15	−20	3,350	47,300	6,600	52,800	15,400	17,000	8,800	100
	A-16	−32	3,600	48,800	6,700	53,800	15,300	17,000	8,600	100
	A-33	−55	3,000	46,500	7,400	54,200	16,500	16,000	9,100	100
	I-34	−64	2,800	48,200	7,500	54,000	8,000	53,700	500	0
	A-29	−60	3,200	47,300	6,000	54,000	6,000	54,000	0	0
	A-30	−42	4,000	48,300	6,700	53,200	6,700	53,200	0	0
Aspect Ratio 8										
I	C-3	0	4,250	76,500	13,750	95,200	13,750	92,500	0	0
II	C-8	21	3,750	72,500	14,500	93,700	37,000	16,000	22,500	100
	C-6	0	3,500	73,700	16,250	94,800	40,000	25,000	23,750	100
	C-5	−10	3,500	71,600	15,000	95,500	15,000	95,500	0	0
	C-7	−20	3,750	74,400	18,100	97,700	28,250	83,000	10,150	25
	C-20	−0	3,370	73,900	15,000	94,800	40,500	20,000	25,500	100
	C-23	−10	3,750	73,700	17,000	95,000	40,700	16,000	23,700	100
Aspect Ratio 16										
	E-1	−10	10,000	140,000	44,000	177,400	118,000	22,000	74,000	100
	E-2	−20	10,000	139,200	33,500	173,000	33,500	173,000	0	0
	E-3	0	12,000	143,600	46,500	177,000	119,000	15,000	72,500	100
	E-15	−21	10,000	140,600	33,250	175,200	33,250	175,200	0	0
	E-16	−10	9,000	136,800	20,000	160,500	20,000	160,500	0	0
	E-27	0	9,500	138,500	32,500	172,000	32,500	172,000	0	0
	E-13	+10	11,000	136,500	45,000	168,300	117,000	20,000	72,000	100
	E-14	0	11,500	140,300	50,000	173,100	125,000	26,000	75,000	100
II	E-6	0	6,300	132,800	54,000	177,700	103,000	94,000	49,000	35
	E-18	−30	6,500	139,500	28,000	170,500	28,000	170,500	0	0
	E-28	20	10,000	139,200	43,000	173,900	108,000	20,000	65,000	100
	E-19	10	8,500	132,800	31,000	169,000	31,000	169,000	0	0
	E-29	30	7,000	133,300	43,300	172,500	101,200	15,000	57,900	100
	E-5	10	7,500	133,000	27,100	166,500	27,100	166,500	0	0
	E-4	0	6,000	133,300	50,900	179,800	64,700	170,000	13,800	16
	E-17	40	6,800	132,300	39,400	172,500	112,300	20,000	72,900	100
III	E-7	30	9,200	135,300	43,000	172,900	101,000	20,000	58,000	100
	E-8	0	7,500	134,200	48,500	175,400	113,500	17,700	65,000	100
	E-9	10	7,500	133,800	43,000	176,300	109,000	60,900	66,000	100
	E-20	−10	8,500	136,800	36,500	174,500	36,500	174,500	0	0
	E-21	0	7,000	133,700	37,500	173,500	37,500	173,500	0	0
	E-30	−10	6,000	134,000	20,500	160,000	20,500	160,000	0	0
IV	E-11	−20	11,000	138,500	52,500	172,600	80,000	130,500	27,500	45
	E-10	0	11,500	140,500	46,500	175,600	116,500	25,000	70,000	100
	E-12	−10	10,500	135,700	33,000	167,500	33,000	167,500	0	0
	E-23	−10	8,000	135,000	41,000	176,000	41,000	176,000	0	8
	E-25	−20	7,500	135,000	48,000	176,700	126,500	29,000	78,500	100
	E-32	−35	7,500	135,000	27,500	167,000	27,500	167,000	0	0
	E-26	−25	5,500	135,000	29,500	166,700	29,500	166,700	0	0
Aspect Ratio 19										
I	F-1	10	9,500	153,000	67,000	201,000	159,000	30,000	92,000	100
II	F-6	20	8,500	154,800	64,000	203,500	155,000	30,000	91,000	100
	F-4	0	7,500	154,000	70,450	206,300	160,000	25,000	89,550	100
	F-5	−20	9,500	160,200	32,250	194,700	32,250	194,700	0	0
	F-22	−10	5,000	154,500	61,000	205,000	152,000	21,000	91,000	100

Specimens in all thicknesses and aspect ratios show no systematic difference in the maximum load as between brittle and ductile types of fracture. Energy to maximum load does not change with type of fracture in aspect ratios of 4 and 8, the energy value for these aspect ratios being the same (barring scatter) in both modes of fracture. Total energy drops to a lower value below the transition temperature in all aspect ratios, but *E2 − E1* is a better indicator of transition temperature. The plot of per cent shear shows the transition temperature in the same way as *E2 − E1*.

The transition temperatures found are shown in Table 17 in 1/2 in. thickness.

Table 17

Aspect ratio	*Block*	*Transition range, ° F.*
4	1	−20 to −10
	2	−35
	3	−35
	4	−32 to −55
8	2	−10
16	1	−10 to zero
	2	Zero to +10
	3	Zero
	4	−20 to −10
19	2	−20 to −10

Based upon these tests it appears that the transition temperature is lower at lower aspect ratios. Variation with edge distance is inconclusive.

In thickness 1 1/2 in., at a single-aspect ratio of 4, energy to maximum load is again found to be the same for brittle as for ductile failure. The transition temperature, however, is higher than that for 1/2 in. thickness by a conclusive margin of about 70°.

It should be recalled that in plates of width 12 in. and thickness 3/4 in., energy to maximum load served as an indicator or criterion of embrittlement since a change in these values occurs at the transition. In that size of plate the transition temperature determined by energy to maximum load agreed with that found from the appearance of fracture. The failure of the same criterion to discriminate between brittle and ductile fracture in the smaller aspect ratios must be explained.

This explanation is to be found in the fact that the localized action around the notch at low-aspect ratio is essentially the same up to the point of maximum load in both types of fracture. In wider plates energy is still localized around the notch but its fractional value in comparison with the energy absorbed by the whole plate falls off quickly as width of the plate increases. In the narrower plates the localized action is thus a larger part of the whole, and when it is large enough to be predominant the energy to maximum load is not affected by the transition from brittle to ductile action.

This simplified explanation ignores the difference between the point of maximum load and the point at which the fracture is established and begins to advance. The distinction between energy before and after maximum load is not the same as the distinction between energy to start and to propagate fracture. No doubt these differences will be found to be significant and further study in detail is being made.

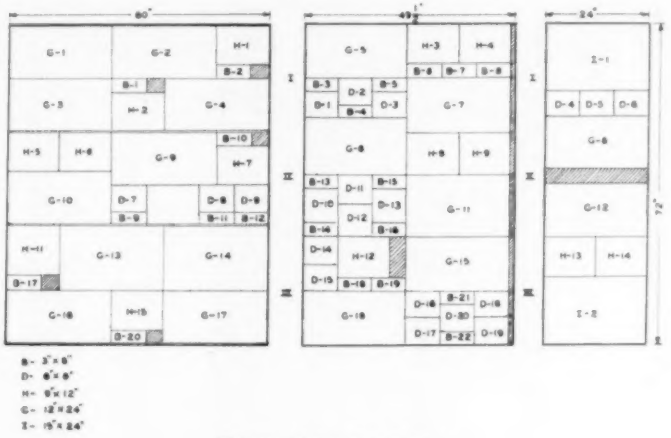

Fig. 55 3/4-in. plate layout

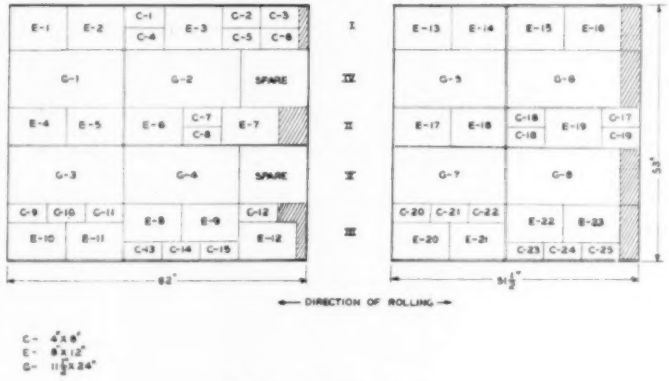

Fig. 56 1-in. plate layout

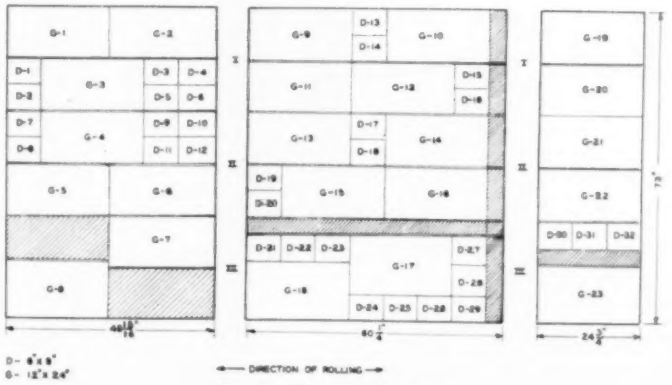

Fig. 57 1 1/2-in. plate layout

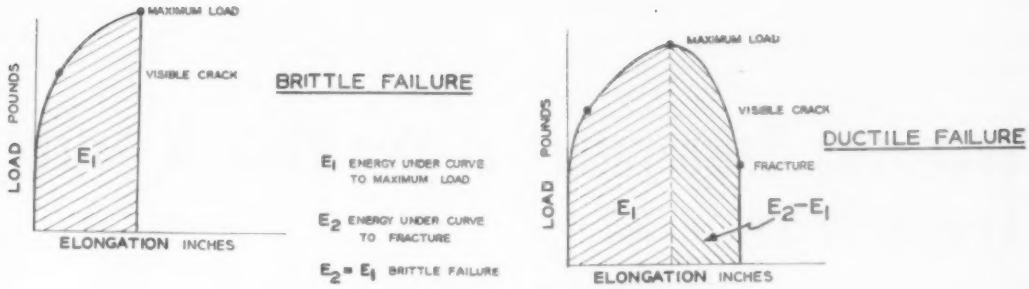

Fig. 58 Typical load vs. elongation diagrams

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The Fracture of Mild Steel*

by C. F. Tipper, M.A., D.Sc.

IN THE COURSE of an investigation into the causes of large fractures in the plating of welded ships, some general information on the fracture of mild steel has been accumulated.

One of the characteristic features of service fractures and those made in the laboratory is the absence of distortion of the plate as a whole. Deformation is confined to a small region, 1 to 2 mm. on either side of the fracture and the separation of the broken parts may also be of this order, even when the fracture is several feet in extent. This is due to the fact that a proportion of the crystals fracture by cleavage.

Sections through the ends of arrested fractures have shown that the center of the plate may be fractured to a depth of 0.2 to 0.45 in., depending upon the thickness of the plate, type of fracture, etc., below the point of visible fracture on the surfaces. The fracture is not continuous across the section and, particularly toward the end, consists of holes separated by unbroken metal or joined by fine cracks. These holes are formed by some crystals breaking before others. If some crystals break by cleavage, their neighbors are relieved of restraint and can continue to deform by shear until they also fracture.

Evidence of the formation of holes some considerable distance from the main fracture front has also been found in steels which break with a wholly fibrous fracture. These holes have been shown to originate by the separation of the metal from nonmetallic inclusions due to transverse stresses which are present in the neck of a tensile test piece and at the bottom of a notch. Such separation leads to the formation of flaws, often visible in fractures, and the final breakdown of the material is by means of the separate extension and fracture of groups or layers of crystals.

The mechanical properties of the material are closely related to the size and distribution of the inclusions which may either hinder or facilitate the passage of a crack.

The paper, of which this a summary, is published in the *Iron & Coal Trades Review*, **157**, 829 (1948), and some of the experimental results upon which it is based in Report No. R. 3., Admiralty Ship Welding Committee, H. M. Stationery Office, 1948.

*Summary of paper presented at the VII International Congress for Applied Mechanics, 1948.

NOTE: This work was carried out in the Engineering Dept. Cambridge University, under the direction of Prof. J. F. Baker, O.B.E., Sc.D.

Transition Temperature of Ship Plate in Notch-Tensile Tests

A comprehensive study of steels under new specifications used in ship construction together with some experimental steels and an evaluation of specimens used in determining notch toughness and transition temperatures of steel for ship construction

by E. M. MacCutcheon, C. L. Pittiglio and R. H. Raring

INTRODUCTION

DURING the past few years, the Ship Structure Committee has sponsored a series of research projects in which notched, full-thickness specimens of ship plate were tested in tension.[1–6] One of the principal goals of these efforts was to determine the minimum specimen width which would simulate the brittle-to-ductile transition characteristics of a "wide" specimen or, by inference, a welded ship. In these investigations, specimens whose widths ranged from 3 to 108 in. were tested, and it was concluded that a 12-in.-wide specimen would provide a reliable index to the ductility-transition behavior of large plates. Consequently, the 12-in.-wide, notch-tensile specimen has become a standard of reference in the research program of the Ship Structure Committee and currently is being used at Swarthmore College[7] and at the David Taylor Model Basin for tests to evaluate the notch ductility of ship steel.

However, since the 12-in.-wide specimen is an expensive one and is too large to be broken in the testing machines available in most laboratories, it cannot be used for routine testing. It is desirable, therefore, to establish the correlation between results from tests of this 12-in.-wide reference specimen and results from tests of the various types of small specimens; to date, however, insufficient data exist to establish such correlation with certainty.

The work reported in the present paper was planned with cognizance of this history of the 12-in.-wide specimen and is part of the program of wide-plate tests sponsored by the Ship Structure Committee.

OBJECTIVE AND SCOPE

The objectives of this investigation were:

1. To increase the volume of data from tests of the 12-in.-wide specimen, which data are useful for correlation with results of tests of various small specimens. To this end, six steels conforming to the old A.B.S. (American Bureau of Shipping) specification for hull steel, three steels conforming to the new A.B.S. specification for hull steel (Class B), and two modified A.B.S. Class B steels were tested.
2. To determine the transition temperature of steels removed from two fractured ships; in this phase of the work 12-in.-wide specimens from six plates were tested.
3. To determine the effect on transition temperature, as determined by the 12-in.-wide specimen, of adding aluminum to two otherwise typical A.B.S. Class B heats of steel.
4. To develop a small, economical tensile specimen for determining transition temperature of steel; eleven of the steels which had been tested with the 12-in.-wide specimen were used for this purpose.

MATERIALS

Plate from "Pierre S. Dupont"

The Liberty Ship *Pierre S. Dupont* suffered several serious cracks of the brittle, cleavage type, while weathering a severe winter storm at sea on Feb. 10, 1948. When this casualty occurred, the air temperature was 27° F. and the water temperature was 42° F.

One of the deck plates (C-10 on the port side) in way of a fracture; but which included neither the source nor the termination of the fracture, was ob-

E. M. MacCutcheon, and **C. L. Pittiglio** were connected with the David Taylor Model Basin and **R. H. Raring** with the National Research Council when this investigation was conducted.

This paper is based upon the final report of a project conducted at the David Taylor Model Basin which will be designated as Model Basin Report No. 709. The work reported herein was sponsored by the Ship Structure Committee as Project SR-105 and by the Bureau of Ships, U.S.N., as NS011-072. Opinions expressed in this paper are those of the authors and are not necessarily indicative of policies of the Navy Dept., the National Research Council or the Ship Structure Committee.

Presented at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

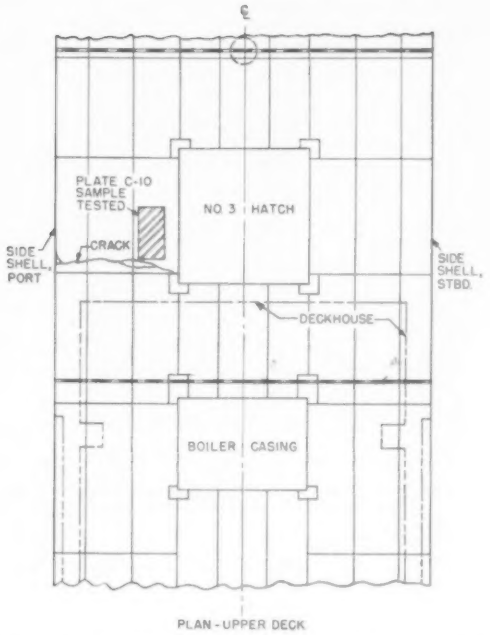

Fig. 1 "Pierre S. Dupont"—Plan view of the upper deck showing the plate removed for testing and the adjacent crack

The crack started in a weld near the corner of No. 3 hatch and was one of several major cracks involved in the casualty

tained for investigation. Seven 12-in.-wide specimens from this plate were tested; Figs. 1 and 2 illustrate the positions of these specimens with respect to the fracture. Specimens from this plate are designated in this report by the letters "DU."

Plates from "Ponaganset"

The T-2 Tank ship *Ponaganset* broke completely in two on Dec. 9, 1947, while moored and under a relatively heavy hogging load. The fracture, which occurred at approximately amidship, was of the brittle cleavage type. At the time of failure, the air temperature and water temperature were 34 and 41° F., respectively.

Samples from five of the plates through which the fracture passed were tested using the 12-in.-wide specimen; Figs. 3 and 4 illustrate the positions of these plates in relation to the path of the crack. The stringer plate, in which the fracture started, was not tested with the 12-in.-wide specimen because there was not sufficient steel available.

In this report the five *Ponaganset* plates are identified by a four-letter code, the first letter of which is "P" (for *Ponaganset*), the second letter indicates the strake, the third letter is either "D" or "S," for "deck" or "side," and the last letter is either "P" or "S" for "port" or "starboard."

Mill Steels

Shortly after the promulgation of the current American Bureau of Shipping specification for ship plate, the Ship Structure Committee procured samples of $^3/_4$-in. plates, some made to the old specification and others to the new specification for Class B material. These plates, which are identified by code numbers S1 to S23 and which represent 16 different heats, were obtained for tests to compare the quality of the steel made to the new specification with that made to the old one. In addition to the tests of the mill steels reported here, other steels from this series are being tested at the New York Naval Shipyard and at Swarthmore College.

In this paper, results of tests of five of the "S" series of plates (S1 through S5), which conform to the new A.B.S. class B requirements, are reported. They were all rolled from middle cuts of the ingots. Plate S1 was coarse-grained and was the only plate from its particular heat; plates S2 and S3 were from one heat, but they differed in grain size; likewise, plates S4 and S5 represent two different grain sizes from one heat.

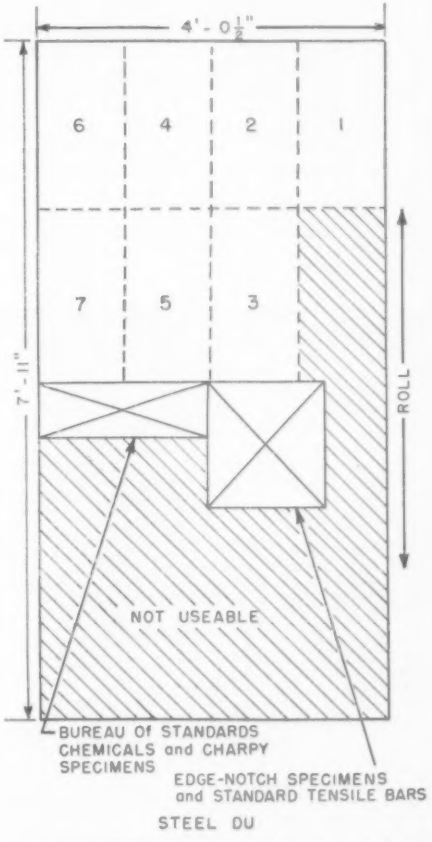

Fig. 2 "Pierre S. Dupont"—Sample from deck plate C-10 showing location of test specimens

Table 1—Chemical Analysis in % of Specimens from *Pierre S. Dupont, Ponaganset* and Mill Heats

Plate	*C*	*Mn*	*Si*	*P*	*S*	*Cu*	*N*	*Type steel**	*Grain size†*
DU	0.26	0.33	<0.02	0.011	0.038	...	...	...	...
PBDP	0.14	0.38	0.00	0.020	0.035	0.16	0.005	Rim	...
PBDS	0.15	0.40	0.00	0.020	0.030	0.17	0.004	Rim	...
PAD	0.22	0.47	0.04	0.021	0.035	0.03	0.004	S-K	...
PCDP	0.14	0.41	0.01	0.027	0.030	0.10	0.004	Rim	...
PJSS	0.29	0.45	0.10	0.015	0.040	0.03	0.0045	S-K	...
S1	0.19	0.67	0.095	0.007	0.037	...	0.0047	S-K	2–4
S2	0.18	0.61	0.055	0.007	0.021	0.05	0.0052	S-K	1–4
S3	0.17	0.61	0.054	0.007	0.020	0.05	0.0046	S-K‡	5–8
S4	0.20	0.92	0.098	0.015	0.040	0.13	0.0038	S-K‡	5–7
S5	0.21	0.90	0.09	0.016	0.040	0.12	0.005	S-K	2–4
Dn	0.22	0.55	0.21	0.013	0.024	0.22	0.004	Si-K	...
E	0.20	0.33	0.01	0.013	0.020	0.18	0.002	Rim	...

* Rimmed, semikilled (S-K) or Si-killed (Si-K).
† McQuaid-Ehn.
‡ The steel for these plates was modified by the addition of aluminum in the ingot mold.

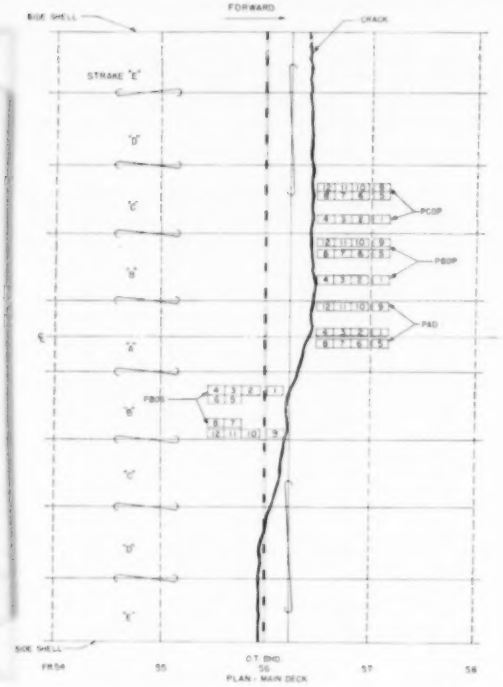

Fig. 3 "Ponaganset"—Plan view of main deck showing the location of test specimens

The crack started in the overlap of two fillet welds around appendages on the main deck. The starting point is about 1 ft. from the starboard side which is at the bottom of the illustration

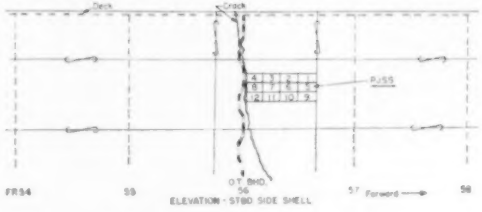

Fig. 4 "Ponaganset"—Elevation of the starboard side-shell showing the location of test specimens in the topside strake

The crack started near the starboard side of the ship in the main deck, which is at the top of the illustration

Table 2—Mechanical Properties of Steel from *Pierre S. Dupont, Ponaganset* and Mill Heats (1-In. Wide Full-Thickness Specimens)

Specimen	*Gage, in.*	*Tensile strength, psi.*	*Yield point, psi.*	*Elongation in 8 in., %*	*R.A., %*	*Bend test*
DU	3/4	60,200	34,400	28.2	...	
PBDP	13/16	52,300	31,900	32.5	...	OK
PBDS	13/16	55,600	32,600	31.0	...	OK
PAD	13/16	59,700	30,500	25.0	...	OK
PCDP	13/16	54,500	34,500	28.0	...	OK
PJSS	3/4	65,200	37,100	27.5	...	OK
S1	3/4	61,400	37,200	27.8	60.0	
S2	3/4	58,900	30,500	34.0	...	
S3	3/4	58,000	29,200	33.0	61.0	
S4	3/4	65,800	35,900	29.0	58.0	
S5	3/4	65,600	38,000	31.0	61.0	
Dn	3/4	67,200	40,500	27.0	50.1	
E	3/4	62,500	38,000	28.0	52.3	

These steels were all semikilled, and the fine grain size of plates S3 and S4 was achieved by the addition of aluminum ($1^1/_2$ lb. per ton) to the ingot molds. In this paper, grain size refers to the austenitic grain size at 1700° F., as determined by the method of McQuaid and Ehn. Particulars of all of the plates tested are given in Tables 1 and 2.

The locations of the specimens in the plates of S1, S2, S3, S4 and S5 are shown in Fig. 5.

CONDITIONS OF TEST FOR 12-IN.-WIDE SPECIMENS

Test Specimen

The test specimen was a 12- x 24-in., full-thickness, notched plate; this plate was loaded by tension in the direction of the longest dimension, which was the direction of rolling. The notch effect was introduced by a 3-in.-long slot perpendicular to the direction of loading and terminating in jeweler's hack-saw cuts approximately 0.012 in. in width. This specimen has been used at the University of California, University of Illinois, Swarthmore College and for previous investiga-

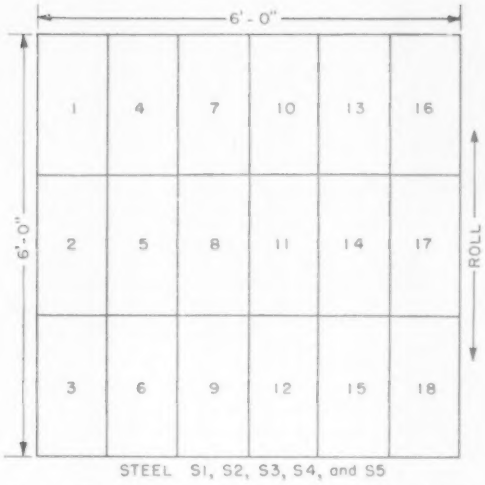

Fig. 5 Mill-Steel Plates S1, S2, S3, S4 and S5 showing the arrangement of 12-in.-wide specimens

tions at the David Taylor Model Basin. Particulars of the specimen are given in Fig. 6.

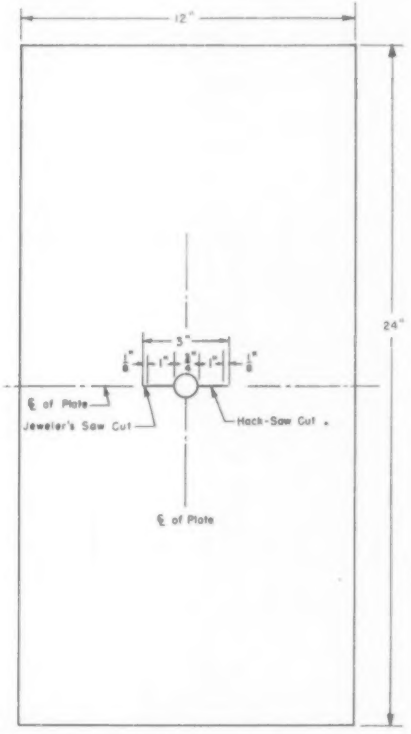

Fig. 6 Twelve-inch-wide-specimen dimensions

Both the direction of rolling and the direction of pulling corresponded to the 24 in. dimension, i.e., perpendicular to the saw-cut notches

Instrumentation

The apparatus for measurement of strain was modeled after that developed at Swarthmore College for similar tests. Twelve spring clips fitted with bakelite-bonded SR-4 strain gages were used, five on each of the specimen's faces and one on each edge. The strain gages were connected by a circuit that averaged the results from all gages on a single strain indicator. Figure 7 shows the gages mounted on a specimen.

The spring clips were mounted on a 9-in.-gage length, which was equal to $^3/_4$ of the width of the specimen. Before each series of tests was started, the strain-gage assembly was calibrated with a dial micrometer.

A mechanical extensometer was rigged between the heads of the specimen to provide elongation data which could be used in the event of failure of the SR-4 gages; no such failures occurred, however, and all the elongation data presented were taken from the wire gages.

Temperature Control

The temperature-control equipment consisted of an insulated storage box for dry ice, a blower and a jacket around the specimen, as shown by Fig. 8. Electric-resistance heaters were located inside the jacket for tests above room temperature. The blower and heater were automatically controlled by a thermostat placed inside the specimen jacket. The exact temperature of the specimen was indicated by two thermocouples embedded in the specimen close to the ends of the slot. Silica gel was placed inside of the dry-ice storage chest to reduce the moisture content of the circulating air and thus prevent corrosion of the equipment and electrical difficulties with the strain gages.

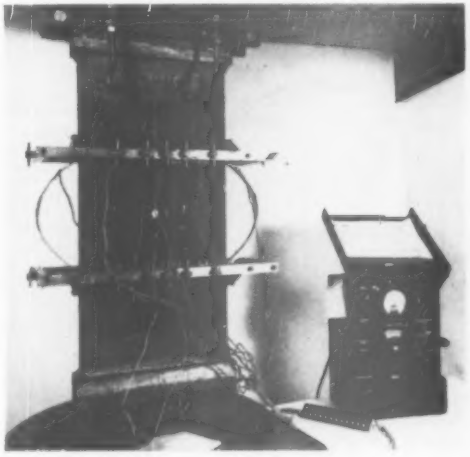

Fig. 7 Twelve-inch-wide specimen welded to pulling headers and set in the grips of the 600,000-lb. testing machine

The twelve 9-in. base-length clip gages are in place. The small triangular contact panel in front of the strain indicator was used to facilitate the detection of defective strain gages

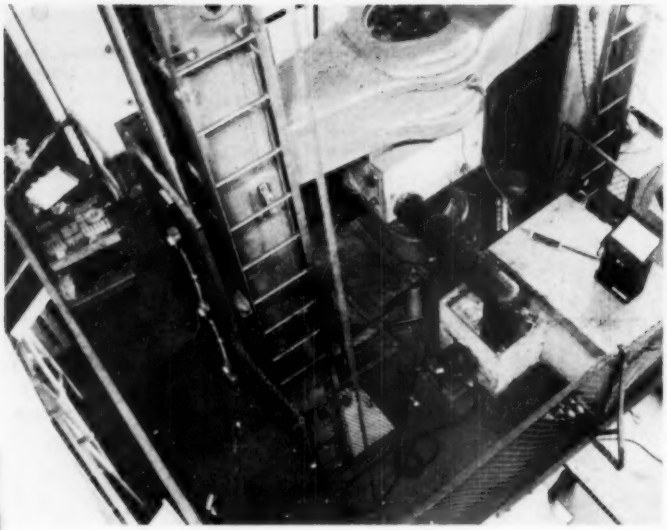

Fig. 8 Twelve-inch-wide-specimen temperature-control equipment

The ice box is on the right under the strain indicator. The motor in the right foreground powers the fan which is buried in a box of sawdust, from the top of which the heavily lagged supply duct goes to the box-shaped jacket around the specimen. On the left side of the jacket the fan-control thermocouple can be seen and to the right the return duct to the ice box

Testing Technique

The tests were performed in a 600,000-lb. universal testing machine at the David Taylor Model Basin.

The rate of application of load was the same for all tests and followed a fixed schedule. The load was increased from zero to yield at the rate of 50,000 lb. a minute; above the yield load, the rate of application of the load was regulated on the basis of the elongation in the 9-in. gage length, as indicated in the table.

Elongation readings were made at 1-min. intervals until the yield load was passed; after yielding, readings were made at 2-min. intervals.

Elongation	*Controlled rate of elongation*
From yield to 0.2 in.	0.01 in./min.
From 0.20 to 0.40 in.	0.02 in./min.
From 0.40 in. to failure	0.05 in./min.

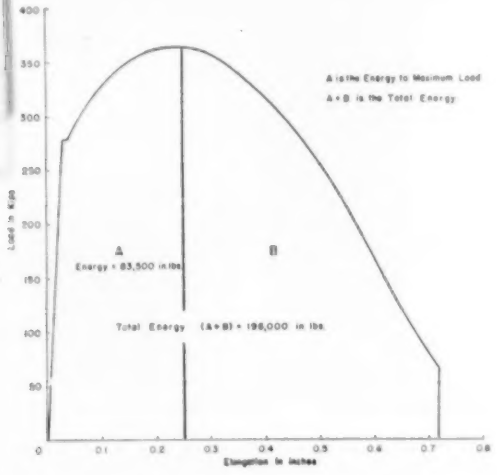
A is the Energy to Maximum Load
A+B is the Total Energy
Load in Kips
A
Energy = 83,500 in lbs
B
Total Energy (A+B) = 196,000 in lbs
Elongation in Inches

Fig. 9 Twelve-inch-wide specimen—Typical load-elongation diagram for a ductile specimen

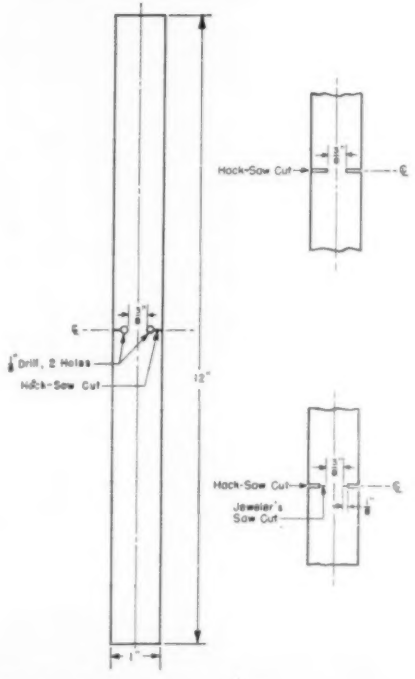

Fig. 10 Dimensions of 1-in. edge-notch specimen

In all of the tests reported the specimens were oriented so that the long dimension corresponded to the direction of rolling of the plate

It was not possible, due to characteristics of the apparatus, to detect the occurrence of the first crack. The small window in the temperature-control jacket did not allow a sufficiently good view of the notch root for observation of the initiation of the crack, and the method of connecting the individual gages had the effect of masking any manifestation of crack initiation by means of the elongation measurement.

Load-elongation curves were drawn for each of the specimens tested, and the area under these curves was measured with a planimeter. From these areas, "energy to maximum load" and "energy to rupture" were determined. Figure 9 shows a typical example of such a curve for a ductile specimen.

The surfaces of the fractures of all specimens were examined, and the amount of fibrous and crystalline area was estimated. Thus the transition temperature could be based on either absorbed-energy or fracture-mode criteria.

1-IN. EDGE-NOTCH TEST

In using the relatively large and costly 12-in.-wide specimen, it is obviously desirable to know the approximate transition temperature before the temperatures for the first few tests are selected. In the investigation of steels from fractured ships this is especially important because frequently the amount of available material limits the number of large specimens that can be manufactured. An effort therefore was made to estimate the transition temperature of the large specimens from results of tests of small specimens.

In this investigation certain economic considerations and mechanical difficulties made the use of any of the more conventional small specimens undesirable. A small edge-notch tensile specimen, therefore, was devised that could be prepared by unskilled personnel and without the use of machine tools other than a power saw and a drill press, and which could be tested in a testing

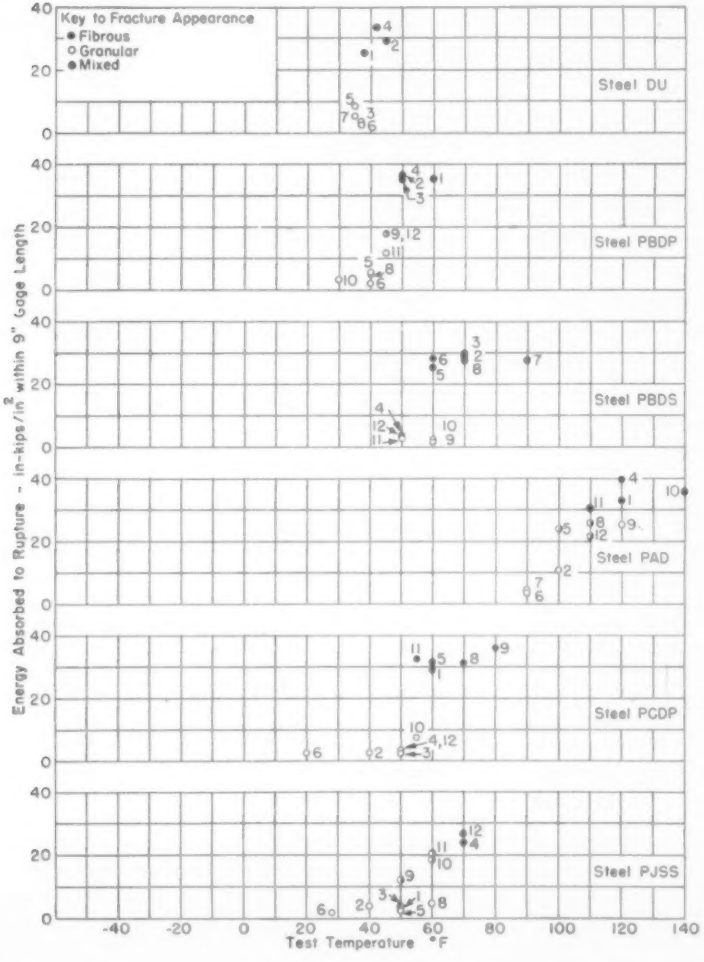

Fig. 11 Twelve-inch-wide specimens—Results of tests of samples removed from fractured ships

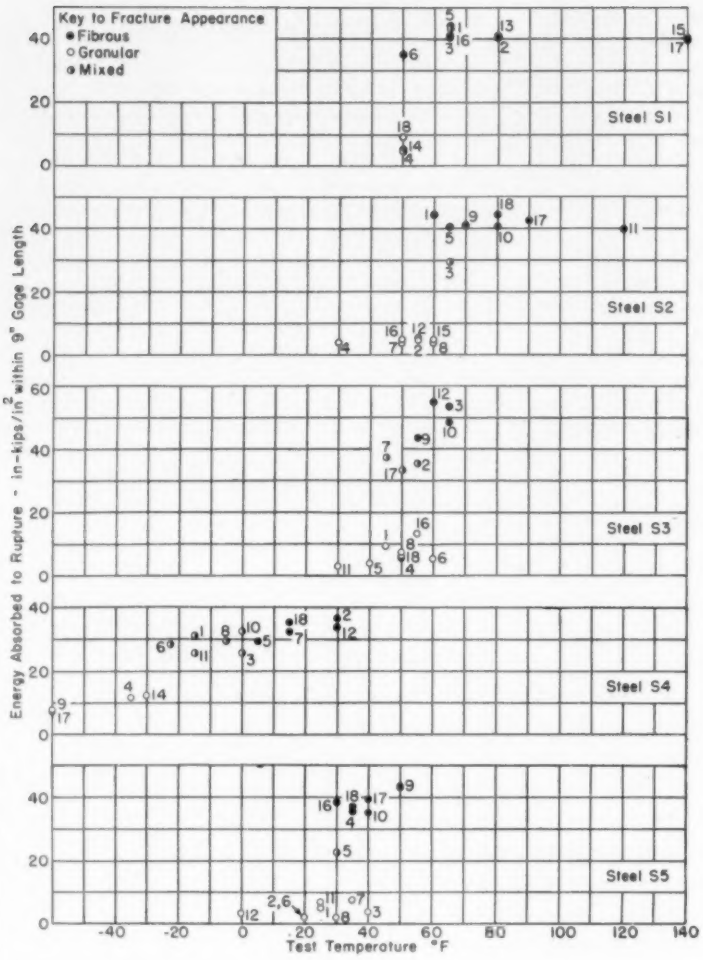

Fig. 12 Twelve-inch-wide specimens—Results of tests of mill steels

machine of 30,000-lb. capacity. Small edge-notch tensile tests are, of course, not novel; Davis, *et al.*,[4] Wagner and Klier,[8] and Tipper[9] have used such tests.

Experimentation was performed with a 1-in.-wide, full-thickness specimen with notch geometries as illustrated by Fig. 10. To achieve control of temperature in the testing of these specimens it was found to be satisfactory to cool the specimens in a suitable bath to some temperature 10 to 20° F. below the desired test temperature and then quickly to transfer the specimen to the testing position in the machine. Thermocouples were embedded in the specimen in the vicinity of the notch root, and the temperature was observed during the course of the test.

The speed of testing was so controlled that failure occurred after approximately 2 min. The temperature of the specimen 60 sec. after the start of the test, at which time the load was 15,000 lb. and appreciable yielding had occurred, was recorded as the test temperature. This temperature differed from the temperature at rupture by 3 to 5° F.

The criterion for ductility with this specimen was the maximum contraction in thickness between the roots of the two notches, a measurement that could be easily and quickly made with a pointed micrometer.

RESULTS

Definition of Transition Temperature

The method used to determine the transition temperature was the one suggested by Osborn, Scotchbrook, Stout and Johnston,[10] in which the observed values of the criterion used for determining the transition temperature were averaged for each temperature and the plotted points so obtained were joined by a series of straight lines. The transition temperature was defined as the point on the curve corresponding to the

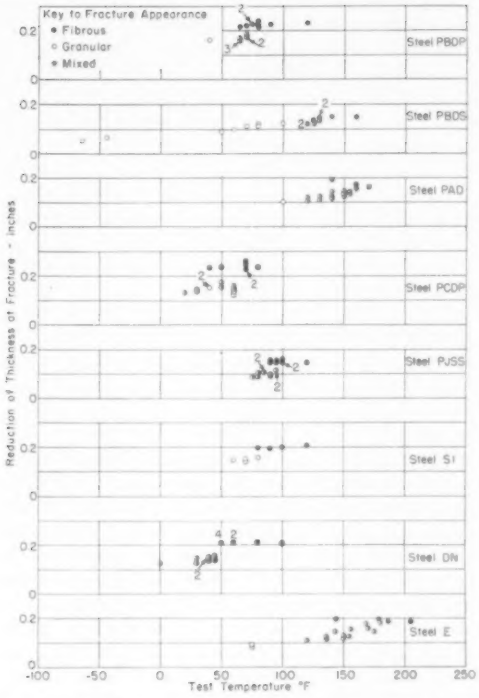

Fig. 13 One-inch edge-notch specimen—Results of tests of specimens with notches terminating in a $^1/_8$-in. diameter hole

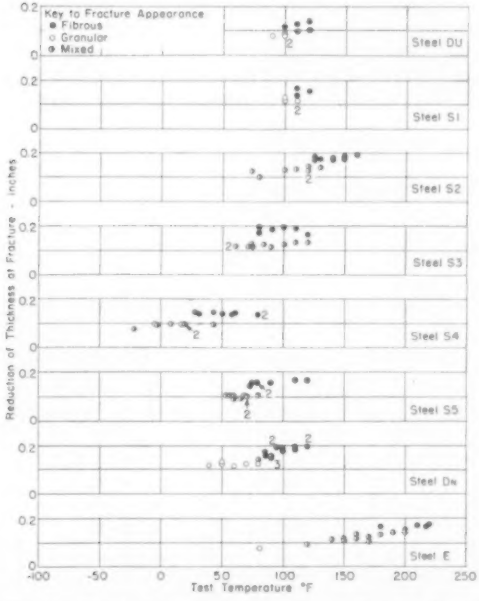

Fig. 14 One-inch edge-notch specimen—Results of tests of specimens with notches terminating in ordinary saw-cuts

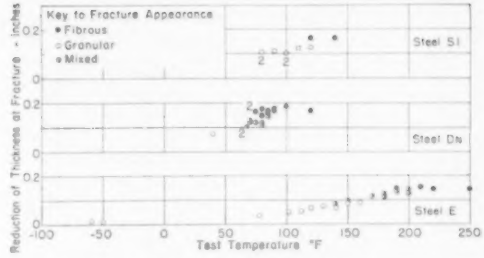

Fig. 15 One-inch edge-notch specimen—Results of tests of specimens with notches terminating in jeweler's saw cuts

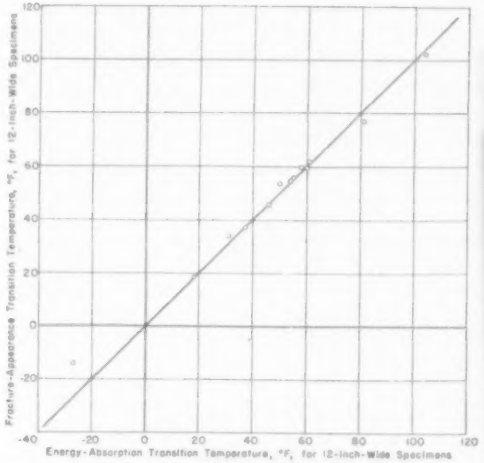
Fracture-Appearance Transition Temperature, °F, for 12-Inch-Wide Specimens
Energy-Absorption Transition Temperature, °F, for 12-Inch-Wide Specimens

Fig. 16 Correlation between transition temperatures by fracture appearance and total absorbed energy, 12-in.-wide specimen

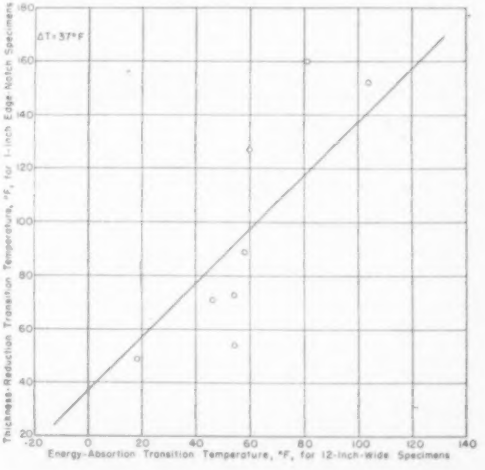
ΔT=37°F
Thickness-Reduction Transition Temperature, °F, for 1-Inch Edge-Notch Specimens
Energy-Absorption Transition Temperature, °F, for 12-Inch-Wide Specimens

Fig. 17 Correlation of results from 1-in. edge-notch specimens with $^1/_8$-in. holes and 12-in.-wide specimens

Table 3—Transition Temperatures in ° F. of Steels as Determined by Various Tests

	12-in.-wide-specimen tests			*1-in. edge-notch tests*					
Steel	*No. tests*	*T. T., Energy to rupture*	*T. T., fracture appearance*	*1/8 in., hole*	*Hack saw*	*Jeweler's hack saw*	*Keyhole Charpy, 15 ft.-lb.*	*V-Notch Charpy, 15 ft.-lb.*	*Navy Tear test*
DU	7	37	37	..	107	..	..	62	..
PBDP	11	46	46	71	..	..	9	..	90
PBDS	11	60	60	127	..	..	18	..	110
PAD	11	104	102	152	..	..	12	..	150
PCDP	11	54	55	54	..	..	−3	..	90
PJSS	11	58	60	89	..	..	−6	..	90
S1	12	54	50	73	118	130	15*	..	100
S2	15	61	62	..	124	..	8*	..	110
S3	15	55	56	..	195	..	6*	..	80
S4	15	−27	−14	..	31	..	−50*	..	−20
S5	15	31	34	..	76	..	−5*	..	70
Dn	28†	18	19	49*	87*	72*	−62*	−18*	70*
E	35†	81	77	160*	180*	175*	27*	90*	140*

* Not the same plate as used for the 12-in.-wide specimens.
† Tests by Swarthmore College and the University of Illinois.

value of the criterion midway between its maximum and minimum values.

12-In.-Wide Specimens

The transition temperatures of the steels, as determined by tests of the 12-in.-wide specimens and according to the criteria, total absorbed energy and fracture appearance, are listed in Table 3. Both stress, in pounds per square inch, and energy, in inch-pounds per square inch, are based on the net effective area of the cross section of the specimen in way of the slot. Data from the individual tests are presented graphically by Figs. 11 and 12.

1-In. Edge-Notch Specimens

Data from tests of the 1-in. edge-notch specimens are presented graphically by Figs. 13, 14 and 15. Numerals opposite plotted points on these figures designate duplicate results. Table 3 lists the transition temperatures of the steels as determined by this specimen, on the basis of the contraction at the root of the notch.

Table 4—Correlation of Transition Temperatures with 12-In.-Wide Specimen Energy-Absorption Transition Temperature

Test specimen	*Criterion*	*No. of steels*	*ΔT, ° F.*	*Deviation, ° F. Maximum*	*Mean*
12-in.-wide Specimen	Appearance	13	1	12	2½
1-in. edge-notch, 1/8-in. hole	Thickness reduction	8	38	41½	20½
1-in. edge-notch H8C	Thickness reduction	8	65	34	11
1-in. edge-notch J8C	Thickness reduction	3	75	20½	14
Keyhole Charpy	15 ft.-lb.	12	−52	40	14½
V-Notch Charpy	15 ft.-lb.	3	−1	35	23⅓
Navy tear test	Energy	12	40	31½	10½

FINDINGS AND DISCUSSION

One of the principal objectives of this investigation was the development of data useful for the establishment of correlation between test results from the 12-in.-wide specimen and those from the various small specimens. This correlation is graphically represented by Figs. 16 through 20. In these graphs, each point represents the transition temperature as determined by each of the two methods being compared. The ΔT indicated is the arithmetic mean of the differences between the transition temperatures of each steel as determined by the methods being compared. The straight lines are drawn at 45° through the value of ΔT. This construction represents a simple, though not necessarily true, relationship between the tests.

For the edge-notch tensile specimens with saw-cut notches, the value of ΔT is based on those specimens with ordinary hack-saw cuts only. The specimens notched with a jeweler's hack saw, however, showed transition temperatures so close to those with the ordi-

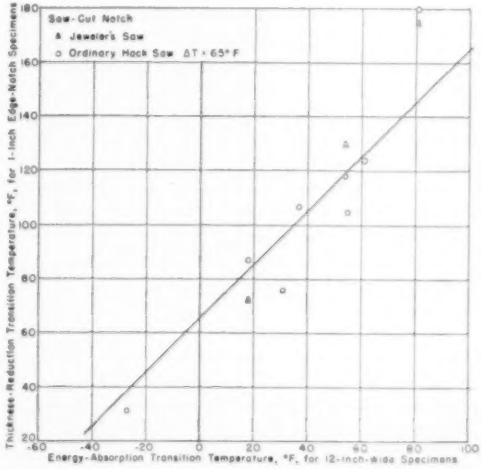

Fig. 18 Correlation of results from 1-in. edge-notch and 12-in.-wide specimens

nary hack-saw cut that both types are plotted on the same graph.

As is evident from Fig. 16, transition temperature on the basis of fracture appearance shows excellent correlation with transition temperature on the basis of absorbed energy for the 12-in.-wide specimen.

Correlation between transition temperatures as determined by the edge-notch tests, the Charpy tests or the Navy tear test on the one hand, and tests of the 12-in.-wide specimens on the other, is poor to fair, as indicated in Table 4, and it must be concluded that precise relationships between the tests are not established.

In comparing results from the Navy tear test and the 12-in.-wide specimen, it should be noted that the definitions for transition temperature differed in the two tests: in the Navy tear test, transition temperature is defined as the highest temperature at which one or more specimens showed an energy-to-propagate value of less than one-half of the energy level of the predominantly shear region, while the transition temperature with the 12-in.-wide specimen was as defined under "Results." However, when the transition temperature by the Navy tear test was determined by using the same definition as was used for the 12-in.-wide specimen, it was found that the scatter in the correlation between results from the Navy tear test and the 12-in.-wide specimen was essentially unchanged and the ΔT was increased by only about 4.5° F. Consequently, the commonly used definition for transition temperature for the Navy tear test was used throughout this paper.

Effect of Addition of Aluminum

It is interesting to note from Table 3 that the addition of aluminum to steel S2 lowered the energy-transition temperature only about 6° F., while the same addition lowered the transition temperature of steel S5 by about 58° F. The grain-refinement effect however, was about the same for both steels, reducing the grain size by 5 or 6 numbers. A very likely explanation for this difference is the observed occurrence of fissuring in steel S4. Thus, in the case of steels S5 and S4, which were from the same heat and differed only in that aluminum was added to steel S4, steel S5 showed no fissures in the 12-in.-wide specimens while steel S4 showed extensive fissuring. In the case of steels S2 and S3, which also were from one heat but differed in that aluminum was added to steel S3, neither showed significant fissures in the 12-in.-wide specimens. The effect of fissuring in lowering transition temperature has been observed previously.[4]

Transition Temperature of Steels Tested with the 12-In.-Wide Specimens

No conclusion as to the role of the steel quality in the failure of the *Pierre S. Dupont* and *Ponaganset* can be justified on the basis of the results in Table 3. While it is true that plate PAD from *Ponaganset* had a relatively high transition temperature, it should be realized that the fracture did not start in this plate but merely traversed it, as it did other plates with lower transition temperatures, e.g., plate PBDP which had a transition temperature 58° F. lower than that of plate PAD.

Likewise, the results of the tests of the ABS Class B steels are insufficient to permit any generalization as to the quality of steels made to the new Class B specification. Judgment of the merits of the specification revision represented by the Class B steel must be based on a broader sampling and further tests.

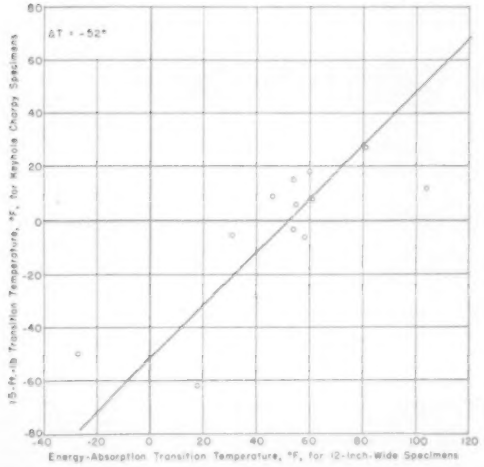
ΔT = -52°
15-ft.-lb Transition Temperature, °F, for Keyhole Charpy Specimens
Energy-Absorption Transition Temperature, °F, for 12-Inch-Wide Specimens

Fig. 19 Correlation of results from keyhole Charpy and 12-in.-wide specimens

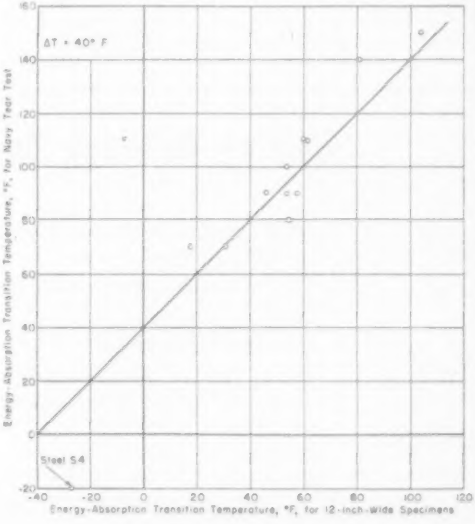
ΔT = 40° F
Steel S4
Energy-Absorption Transition Temperature, °F, for Navy Tear Test
Energy-Absorption Transition Temperature, °F, for 12-Inch-Wide Specimens

Fig. 20 Correlation of results from Navy tear test and 12-in.-wide specimens

1-In. Edge-Notch Tension Test

In the course of testing the 1-in. edge-notch tensile specimens, it was observed that those specimens which were covered with mill scale frequently revealed yielding by the sudden separation of scale flakes. This yielding was studied in several specimens by means of a lateral-contraction gage located at the notch root in order to determine how the nominal stress at yielding in the edge-notch specimens compared with the yield point as determined by conventional unnotched tensile specimens. Results of these preliminary studies showed that while some edge-notch specimens had a sharply defined yielding, other specimens did not, and a definite yield phenomenon in the edge-notch specimens could not be correlated with the yield point as determined by unnotched specimens. These preliminary studies were therefore abandoned.

Correlation with results from tests of the 12-in.-wide specimen indicates that the edge-notch specimen with a saw-cut notch can predict transition behavior in the large specimen at least as well as other small specimens.

CONCLUSIONS

Transition temperature as determined by the 12-in.-wide specimen is essentially the same by either the absorbed-energy or the fracture-appearance criterion.

Since this investigation represents only one phase in a series of wide-plate tests, no other general conclusions are warranted on the basis of the data presented in this paper.

ACKNOWLEDGMENT

A considerable amount of the data used for correlation of test results was supplied by N. A. Kahn of the New York Naval Shipyard, J. L. Wilson of the American Bureau of Shipping, and Dr. Morgan L. Williams of the National Bureau of Standards; certain of these data were received in private communications. Permission to use data from all of the above sources is gratefuliy acknowledged. Completion of the tests could not have been accomplished without the assistance of P. E. Humphries and E. H. Boblits of the David Taylor Model Basin. The plates from the *Ponaganset* were secured through the cooperation of the Boston Naval Shipyard.

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AMERICAN WELDING SOCIETY

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Evaluation of Tests for Steels for Welded Structures

Selection of test specimens for use as indices of performance of steels in welded structures. Weldability of steels and the influence of welding upon the performance of large welded structures

by P. J. Rieppel, R. G. Kline and C. B. Voldrich

INTRODUCTION

MANY test specimens and testing procedures have been developed during the past decade to provide criteria for selecting materials and welding procedures for use in making welded structures. Interest in this field was stimulated greatly by the increased use of welding for all types of structures, including ships. This work was initiated in Europe as a consequence of failures of welded bridges, and, in this country, principally of failures in welded ships during and since World War II. The objective of the work reported here was to obtain information on weldability of steels and the influence of welding upon the performance of large welded structures. The effects of design, known to be profound, have but seldom been considered in previous work, or in the work described by this paper. Various specimens, both large and small, were used, ranging in size from Charpy notched-bar specimens to full-scale sections of hatch corners of ships.

Some of the objectives of this work have been to: (*a*) determine the causes of brittle failure of ships; (*b*) develop a commercial steel which has optimum properties for welded ships and (*c*) develop a test specimen and procedure which can be used to check the usefulness of steels for large welded structures.

A project was started at Battelle in July 1947, to pursue the last of these objectives. The principal objective of this research was to evaluate the usefulness of various small mechanical test specimens for indicating the performance of large welded structures. Another objective was to study fundamental factors contributing to the performance of such welded laboratory specimens.

A survey was made of published literature and unpublished reports which deal with this general subject. The test specimens described in various works were cataloged and appraised for studying strength, ductility, and notch toughness of welded joints in structural steels. On the basis of this survey, four of the most promising specimens were selected for further evaluation.

Test materials were ship-grade steels which had been studied by means of many other types of specimens. Among the specimens used previously on the steels were full-scale hatch-corner specimens at the University of California. The basic premise was that a small test which evaluated the selected steels in the same way that the hatch-corner tests did would be worthy of further study as a possible test specimen to evaluate steels, or to predict their performance in large welded structures.

Studies were made with the small selected specimens and several modifications of the ones which proved to be the most promising. Studies were also made on weld metals used in preparing the specimens, and the effect of preheat and postheat upon the performance of the welded test specimens.

This paper is presented as a report on an investigation which is still in progress. The work described was done from July 1, 1947, to July 1, 1949.

LITERATURE SURVEY

The literature from 1932 to 1947 was surveyed to review the various types of weldability specimens which have been used to study strength, ductility and notch toughness or low-temperature brittleness of welded joints in structural steels. The specimens, there recorded, have been used for determining: (1) the effects of welding on ductility and susceptibility of a steel to cracking; (2) the mechanical properties and over-all efficiency of welded joints; (3) the notch

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toughness of weld metals, heat-affected zones of welds and base plate; (4) the strength and soundness of weld metal and (5) the expected service life of a structure under different conditions of loading and temperature. A great many of the specimens surveyed were considered not applicable to the present investigation.

A large number of factors had to be considered in selecting specimens for evaluating the effect of welding on medium-carbon hull steels, and predicting the behavior of the welded structure under service conditions. The specimen should be small, and easy to make and to test. Variation in steel, weld metal and welding procedure should be reflected by the performance of the specimen during testing. The specimen and testing should simulate the service requirements of a weldment, such as rigidity, loading and temperature variation. Therefore, the only specimens considered during the survey for further study were those that simulated a weldment, i.e., contained weld metal, heat-affected metal caused by welding and base metal.

The types of specimens found by the survey were roughly divided into the following five groups based on the method used for testing them: (1) bend tests; (2) tension tests; (3) rapid loading or impact-type tests; (4) cracking or restraint-type tests and (5) fatigue tests.

The cracking or restraint-type tests were generally excluded from further consideration. This was done because these tests were designed and used chiefly to determine the tendency of steels or weld metals to crack during or after welding. While this is an important factor in the over-all study of weldability, these specimens did not fit the requirements of a test to study the performance of an entire welded structure.

The impact-type tests were seriously considered for various aspects of the investigation, but the construction of falling-weight machines is expensive and their operation is not simple. Perhaps of even greater moment was the conception of failure as due to concentrated and multiaxial stresses, instead of the impact of wave action and, therefore, the critical tests have been of the notched type. Another premise was set up, namely that evaluating the transition properties of weld metal or selected parts of the heat-affected zones of the weld would provide the desired appraisal. However, much of this type of study has been conducted by other investigators in other phases of the Ship Structure Committee research program, and it was believed that further testing of this kind was not needed. Furthermore, this type of test could not be used easily with standard equipment available to test an entire weldment which contained a weld, heat-affected zone and a reasonable amount of unaffected base material.

The fatigue tests were generally excluded from immediate use, because they were not directly applicable to the initial phases of the investigation. While fatigue may play its part in some ship failures, it was also held to be subordinate to the sudden brittle type.

For further analysis, the bend and tension specimens were separated into types having notches and those without notches. Of the specimens without machined notches, the tee-bend test specimen was selected for further study. This specimen was selected because it is representative of a typical welded structure found in ship construction, and other investigators have found it suitable for rating steels for welded structures.

Many bend specimens contained machined notches of various types to produce a high degree of constraint in the critical section of the specimen being tested. Most of these specimens have been used for evaluating the relative properties of various steels used for specific types of weldments. Typical of this type of specimen were those having a longitudinal weld bead and transverse notch across the specimens.

Tension specimens with and without notches were considered, and one with a longitudinal weld bead with transverse notch was selected for use in the investigation. This was very similar to some of the bend specimens, the only difference being the method used in testing.

The details of the specific specimens selected for this work are shown in Figs. 1 to 5. The details of the many specimens surveyed, and a bibliography of the references studied, are given in a report, Serial SSC-23, by Committee on Ship Construction.

The various types of tests cataloged from this literature survey were considered by the investigators and

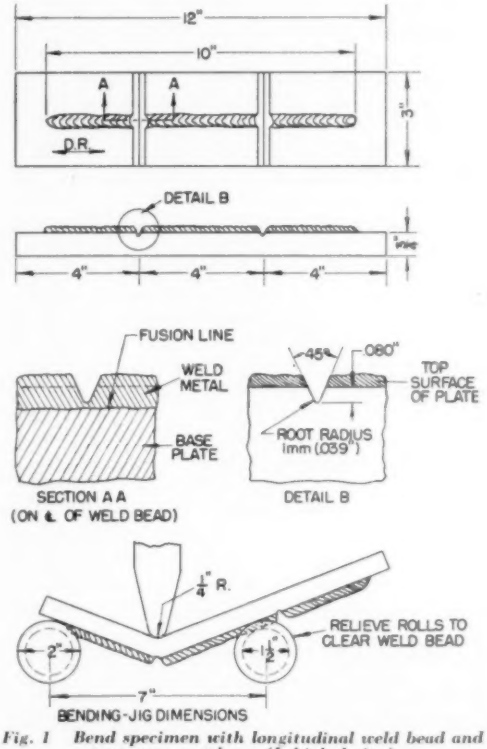


Fig. 1 Bend specimen with longitudinal weld bead and transverse notches. (Lehigh design)

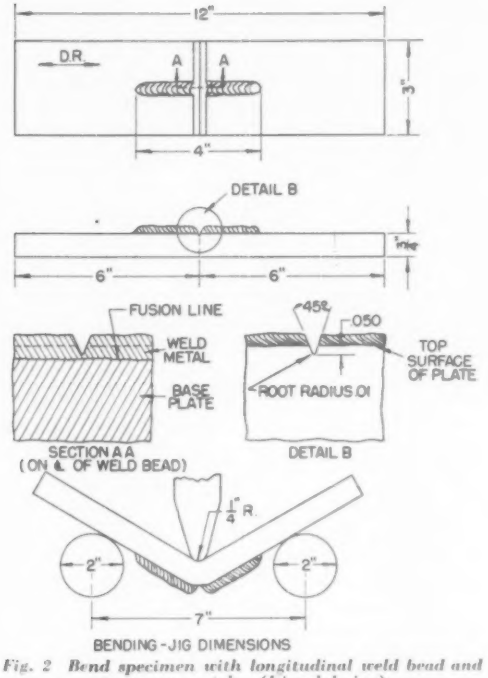


Fig. 2 Bend specimen with longitudinal weld bead and transverse notch. (Kinzel design)

Project Advisory Committee. It was decided to further investigate: (1) specimens having a longitudinal bead and transverse notch; (2) the tee-bend specimen, which represents a typical welded ship joint and (3) a longitudinally welded transversely notched tension specimen.

STEELS STUDIED

Two semikilled, as-rolled medium-carbon ship steels, designated as "Br" and "C," were used for the initial phases of the investigation. These steels were set aside by the Bureau of Ships for research. They were selected for this work because they previously exhibited the best ("Br") and poorest ("C") properties of the

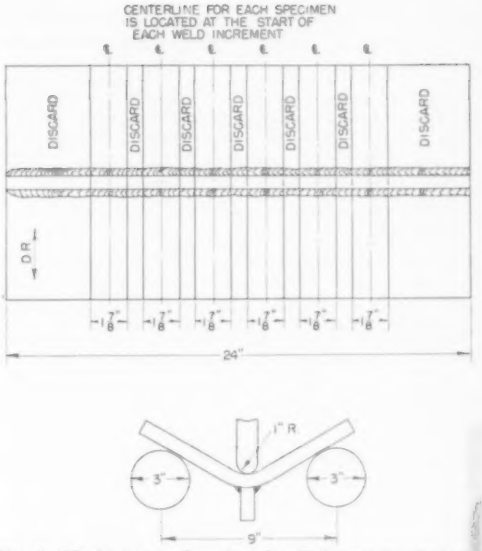


Fig. 4 Machining and testing details for tee-bend specimen

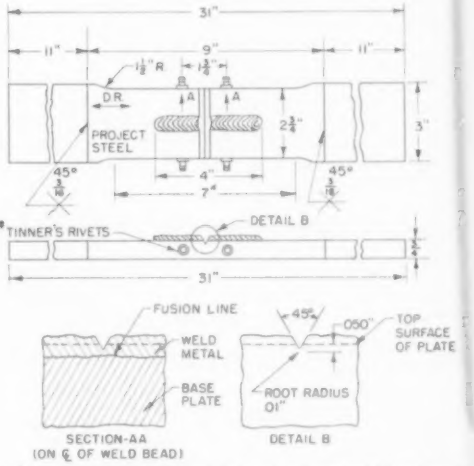


Fig. 5 Tension specimen with longitudinal weld bead and transverse notch

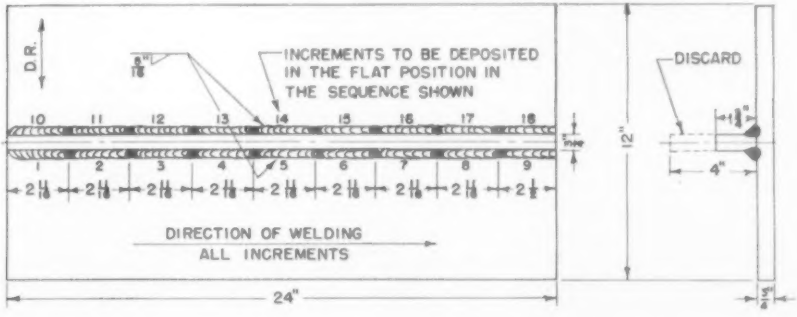


Fig. 3 Welding details for tee-bend specimen made from 3/4-in. plate

Table 1—Mechanical Properties and Chemical Compositions of Steels Studied

Steel Code letter	Type of steel	Thickness, in.	Steel condition	Mechanical Properties: Yield point, psi.	Ultimate strength, psi.	Elongation in 2 in., %	Elongation in 8 in., %	Reduction in area, %	Hardness, rockwell B
Br	Semikilled	3/8	As-rolled	32,200–34,600	55,600–58,600	43	33	58–71	58–63
C*,†	Semikilled	3/4	As-rolled	34,500–37,600	61,500–68,500	35–43	32	58–63	66–69
A*,†	Semikilled	3/4	As-rolled	35,400–36,700	57,600–62,900	45	32–37	53–62	58–62
W‡	Killed	3/4	As-rolled	37,200	62,500	...	30	...	...

Steel code letter	C	Mn	Si	P	S	Cr	Ni	Mo	Cu	Al	Sn	N
	Chemical Composition, %											
Br*	0.18	0.73	0.07	0.008	0.030	0.03	0.05	0.006	0.07	0.015	0.012	0.005
C*	0.24	0.43	0.05	0.012	0.026	0.03	0.02	0.005	0.03	0.016	0.003	0.009
A*	0.26	0.50	0.03	0.012	0.039	0.03	0.02	0.006	0.03	0.012	0.003	0.004
W‡	0.20	0.52	0.23	0.013	0.010	0.07	0.10	0.010	0.17	0.006	0.035	0.005

* Boodberg, A., H. E. Davis, E. R. Parker, and G. E. Troxell, "Causes of Cleavage Fracture in Ship Plate—Tests of Wide Notched Plates," The Welding Journal, **27** (4), Research Suppl., 186-s to 199-s (1948).

† The data for the mechanical properties are the lowest and highest values obtained for each steel.

‡ Kahn, N. A., and E. A. Imbembo, "Notch Sensitivity of Steel Evaluated by the Tear Test," The Welding Journal, **28** (4), Research Suppl., 153-s to 165-s (1949).

steels used in the full-scale hatch corner and other tests.

In the later phases of the investigation, a semikilled steel "A," and a fully killed steel "W," were studied. All four steels were used in 3/4-in. plate thickness.

The mechanical properties and chemical compositions of these steels are given in Table 1.

Welding Electrodes Used

The major part of the welding in this investigation was done with 3/16-in. E6010 electrodes. A few comparative tests were made with E6020 electrodes.

PREPARATION AND TESTING OF SPECIMENS

The preparation of the welded specimens involved three steps: (1) preparation of plates for welding, (2) welding and (3) machining the samples for testing. Unwelded specimens required only machining. The specimens were heated or cooled to the desired test temperatures, and then bend tested or tension tested, depending upon the type of specimen.

The details of the preparation and testing of these specimens are given in Appendix A.

DEFINITION AND INTERPRETATION OF TRANSITION TEMPERATURE

In this investigation, as previously stated, it was desired to find a small welded specimen which could be used to evaluate the usefulness of ship-grade steels for large welded structures. The transition temperature of the ship steel being studied, as determined by the original full-scale hatch-corner specimen, was considered to provide the significant index of usefulness of the steel for large weldments. That is, if this transition temperature was high, and little energy was absorbed by the specimen at relatively high temperatures, that steel was considered less desirable for large weldments than one which gave a low transition temperature. These were held to be the only data available, or the most reliable data, which gave a direct measure of performance of steels in large welded structures.

It is recognized that the validity of any correlation between the test specimen and the full-sized structure depends on the degree to which the secondary standard (the hatch-corner test specimen) actually represents a ship or large structure. This hatch corner was not of a good design (deliberately so, for experimental purposes) and was so welded that the weld, not the steel, was the weakest point. Consequently, when the welds failed, the steel was subjected to conditions of stress that should not be encountered in normal good design. However, this phase of the broad problem was not part of the present study, and a better statement of the objective would be the development of a small specimen whose behavior would correspond to that of the hatch-corner specimen.

For the program as laid out, the transition temperatures of the project steels were determined with each of the small specimens used. No one specimen was found which matched the hatch corner, and in later work various modifications of the specimens were also used in an attempt to improve the correlation. However, before transition temperatures could be determined for these small specimens, definitions of transition temperature and methods of determining it had to be considered.

The "transition temperature" is that temperature at which the behavior of a given material, in the shape of a specific test specimen and stressed in a specific way, changes from ductile to brittle behavior. To determine this temperature, it is customary to plot some measure of ductility, obtained from testing specimens over a range of temperatures, and then to draw the transition-temperature curve. It is then necessary to select the transition temperature from the curve by some standardized method, an operation that is by no means simple and straight forward. Many criteria of ductility were considered and several were tried out for plotting transition-temperature curves. Also, several different methods were considered for locating the transition temperature on a given curve.

Criteria Used for Plotting Transition-Temperature Curves

The most commonly used values for plotting transition-temperature curves are listed as follows:

1. Energy absorbed by specimen.
   - (*a*) Energy absorbed to maximum load.
   - (*b*) Energy absorbed after maximum load.
   - (*c*) Total absorbed energy.
2. Bend angle of specimen.
   - (*a*) Bend angle at maximum load.
   - (*b*) Bend angle after maximum load.
   - (*c*) Total bend angle.
3. Lateral contraction of specimen at root of notch after failure.
4. Fracture appearance or per cent cleavage fracture.

All of the methods listed above were used in plotting transition-temperature curves for all of the various series of bend-test specimens studied. For the tension tests, the data used were maximum load, absorbed energy to maximum load and fracture appearance. The detailed data from all of these tests and the detailed curves are not included in this paper because of the space required. These data can be found in Ship Structure Committee Reports, Serial Nos. 23 and 33.

The transition-temperature curves based on absorbed-energy measurements, bend angle and lateral contraction were very similar, so that transition temperatures determined from these data were usually the same. This is reasonable, since they reflect the ductile behavior of the steel. For this basic reason, and also to conserve space, it was decided to use only the transition temperature determined from measurements of absorbed energy to maximum load in this paper.

On the other hand, the transition-temperature curves based on fracture appearance generally resulted in different transition temperatures than those obtained by absorbed energy. The "fracture" transition temperature was often higher than the absorbed energy or "ductility" transition temperature. The difference between these two transition temperatures varied with the steels tested. For example, some steels in Kinzel-type specimens absorb a great amount of energy and bend considerably, yet fail suddenly with a brittle-type (i.e., brittle or granular in appearance) fracture. Thus, a fracture which is brittle in appearance (macroscopically) could be preceded by considerable deformation and energy absorption. In a case of this kind, there was an important difference between the "fracture" transition temperature and the transition temperature determined by absorbed energy. The "fracture" transition was usually higher than the "ductility" transition temperature. Of the two criteria, fracture and absorbed energy, the latter showed the most about the behavior of the steel in these specimens. It is only when the absorbed energy is at the low level, and remains at that level with further lowering of the test temperature, that truly brittle behavior occurs. At all temperatures above this point, there is always appreciable deformation before fracture and hence considerable absorption of energy. However, a fracture which occurs after deformation and absorption of

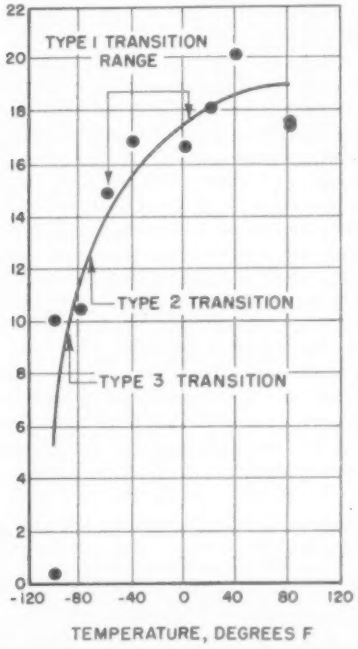


Fig. 6 Location of transition temperature for unwelded Kinzel-type specimens of "Br" steel determined by various methods and using the absorbed-energy curve

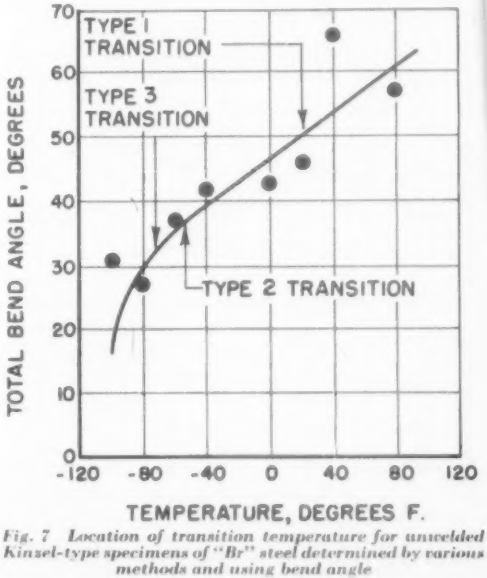


Fig. 7 Location of transition temperature for unwelded Kinzel-type specimens of "Br" steel determined by various methods and using bend angle

energy may appear (macroscopically) just as brittle as the one resulting from truly brittle behavior.

A better method of classifying these fractures would be by "fractography"* which has recently been used by Baeyertz and associates to study fractures of Charpy bars.†

Methods of Selecting Transition Temperatures from Average Curves

The method of selecting transition temperatures from an average curve depends upon the definition or specific criterion used for transition temperature. Some criteria commonly used in selecting the transition temperature from an average curve follow:

Type 1. The temperature of the first significant decrease in absorbed energy, bend angle, lateral contraction, etc.

Type 2. The temperature on the average curve at the midpoint between the upper and lower limits of the curve.

Type 3. The temperature coordinate of the point on a transition-temperature curve which represents half of the maximum value of the curve.

Figures 6 through 9 illustrate the variations in transition temperature that are obtained when the same data are analyzed on the basis of the various definitions of transition temperature given above.

The transition temperature determined from the curve in Fig. 6 ranges from −90° to 0° F., depending upon which definition is used. The Type 1 transition could not be accurately located because there was no sharp drop in the curve indicating the ductile to brittle transition of the material.

* Zapffe, C. A., and Clogg, M., Jr., "Fractography—A New Tool for Metallurgical Research," *Trans. Am. Soc. Metals*, **34**, 71–97; discussion, 98–107 (1945).

† Baeyertz, M., Craig, W. F., and Bumps, S., "A Metallographic Description of Fracture in Impact Specimens of Structural Steel," *Metals Trans.*, Vol. 185, 481–490, August 1947.

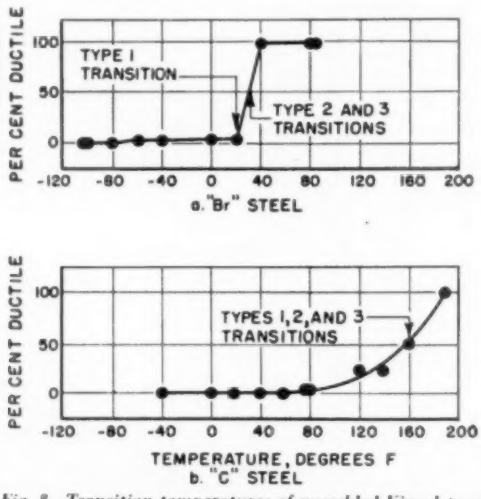


Fig. 8 Transition temperatures of unwelded Kinzel-type specimens of "Br" and "C" steels determined by various methods and using fracture appearance

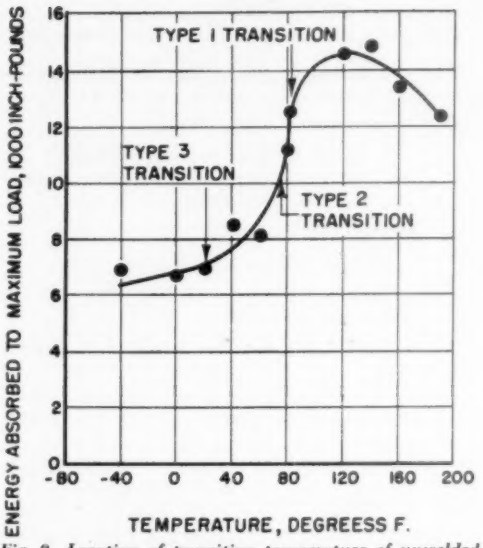


Fig. 9 Location of transition temperature of unwelded Kinzel-type specimens of "C" steel determined by various methods

The bend angle (at maximum load) vs. temperature curve of "Br" steel for unwelded Kinzel specimens, shown in Fig. 7, shows the same general variations in transition temperature when different definitions are used. Depending on the definition, the transition temperatures vary from −70° to 20° F.

The transition range shown by the curve in Fig. 8, which was based on fracture appearance vs. temperature for the same type specimen and steel, was considerably narrower than those shown by the curves in Figs. 6 and 7, which were established on the basis of absorbed energy and bend angle. The transition temperature from the curves in Fig. 8 would be about the same regardless of the method used for determining it.

Figure 9 shows an absorbed energy vs. temperature curve for unwelded Kinzel specimens of "C" steel. In this particular case, the Type 1 and Type 2 transition temperatures coincide. This is usually true when there is a sharp slope to the curve.

For consistency in this paper, the Type 1 transition temperature is always used. It was selected from average curves plotted from measurements of energy absorbed to maximum load and from macroscopic fracture appearance.

INITIAL STUDIES WITH SELECTED SPECIMENS ON "Br" AND "C" STEELS

The initial studies were conducted on the "Br" and "C" steels because these steels had shown the greatest differences in properties by the hatch corner and other tests. The transition temperatures of these steels were determined by the Kinzel, Lehigh, tee-bend and tension tests. For a comparison of welded and unwelded

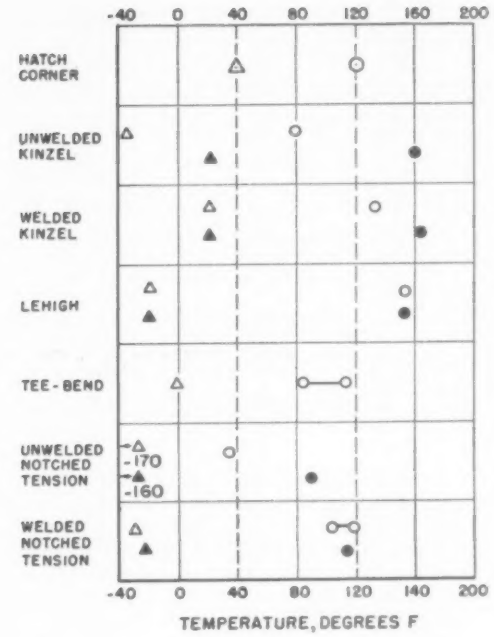

-40 0 40 80 120 160 200
HATCH CORNER
UNWELDED KINZEL
WELDED KINZEL
LEHIGH
TEE-BEND
UNWELDED NOTCHED TENSION
-170
-160
WELDED NOTCHED TENSION
-40 0 40 80 120 140 200
TEMPERATURE, DEGREES F
△ - "Br" STEEL - ABSORBED ENERGY TO MAXIMUM LOAD
▲ - "Br" STEEL - FRACTURE APPEARANCE
○ - "C" STEEL - ABSORBED ENERGY TO MAXIMUM LOAD
● - "C" STEEL - FRACTURE APPEARANCE

Fig. 10 Comparison of transition temperatures of "Br" and "C" steels obtained from various tests with those obtained from hatch-corner tests

specimens, unwelded Kinzel-type specimens, and unwelded tension specimens, were made on both "Br" and "C" steels.

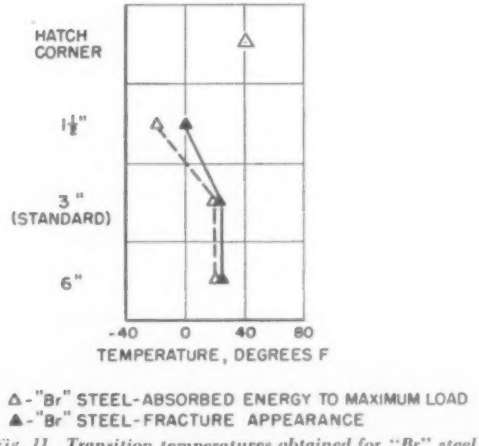


Fig. 11 Transition temperatures obtained for "Br" steel with Kinzel specimens of different widths

A summary of the transition temperatures obtained, based on energy absorbed to maximum load and fracture appearance, is given in Fig. 10, and compared with those obtained by the hatch-corner specimen.

On the basis of these data, all of these test specimens showed the "Br" steel to have a lower transition temperature than the "C" steel. These results were in the same order as results from all other tests used in other investigations of these steels. The welded specimens had higher transition temperatures than the unwelded specimens which, on this basis, indicated that welding decreased the performance of the steels.

These data were considered by the investigators and the Project Advisory Committee. It was decided that the Kinzel specimen and the tee-bend specimen were the most likely, of those studied, to give the same transition temperatures as the hatch-corner specimens. On this basis, it was decided that these specimens should be given further evaluation tests.

INFLUENCE OF SPECIMEN DETAILS AND PREPARATION ON TRANSITION TEMPERATURE OF "Br" AND "C" STEELS

The Kinzel specimen was varied by changing its width and notch depth. The immediate objective was to raise the transition temperature of the "Br" steel from 20° to 40° F., and lower the "C" steel transition temperature from 130° to 120° F.

The tee-bend specimen was chosen for further research because the transition temperatures obtained with it for the "Br" and "C" steels were both lower than the respective hatch-corner transition temperatures, as shown by Fig. 10. Thus, it seemed feasible that a modification of this type of specimen could be made so that the hatch-corner transition temperature could be duplicated. Therefore, the welding procedure and the specimen width was changed in an attempt to obtain the desired shift in transition temperature.

Influence of Specimen Width on Transition Temperature of Kinzel Specimens

Two series of Kinzel specimens were tested. The specimens of one series were $1^1/_2$ in. wide and the others were 6 in. wide. All of the specimens were made from "Br" steel and were welded with E6010 electrodes. The welding schedule was the same as used for standard 3-in. Kinzel-type specimens.

The results of these tests are summarized in Fig. 11. The transition temperatures given are Type 1. They are based on absorbed energy to maximum load and fracture appearance, and are compared with those of the hatch-corner specimens.

The increase in specimen width from 3 to 6 in. had little effect on the transition temperature of the "Br" steel. Specimens of "C" steel were not tested because of the results obtained with "Br" were not encouraging, and the supply of "C" steel available was small.

Influence of Notch Depth on Transition Temperature of Kinzel Specimens

Kinzel-type specimens 3 in. wide of "Br" and "C" steels having a notch depth of 0.090 in. were prepared. These specimens were welded with $^3/_{16}$-in. E6010 electrodes using the same welding conditions used for standard specimens. It was desired that these specimens have a notch sufficiently deep to eliminate the weld metal, but not to penetrate below the fusion line and into the heat-affected zone at the bottom of the weld. This was done to study the influence on specimen performance of removing the weld metal as well as of notch depth. Macrosections of several typical welds indicated that a notch depth of 0.090 in. below the plate surface would be satisfactory for these specimens; therefore, the notches were machined 0.090 in. deep.

The results of these tests are summarized and are compared with those of standard specimens and the hatch-corner test results in Fig. 12. The results showed that the change in design of specimen raised the transition temperature of both steels. The transition temperature of the "Br" steel was raised from the 0° to 40° F. range to 40° to 100° F. range. However, the transition temperature of the "C" steel was changed only slightly by the increase in notch depth. In the case of "Br" steel, as shown in Fig. 12, the fracture-appearance transition temperature of specimens with 0.090-in. notch was lower than the transition temperature based on energy absorbed to maximum load. This is opposite to what has usually been observed, i.e., fracture transition temperatures have usually been higher.

Influence of Welding Schedule Changes on Transition Temperature of Tee-Bend Specimen

Experience on this project indicated that the greatest disadvantage of the tee-bend test over some other tests was the difficulty in adhering to the welding requirements. It was not easy to produce the size of welds required with the $^5/_{32}$-in. electrode specified for the test. Consequently, a $^3/_{16}$-in.-diameter electrode was used instead of a $^5/_{32}$-in.-diameter electrode, and a welding schedule was set up by which a $^3/_{16}$-in. fillet would be deposited with slightly less heat input per inch of weld than that deposited by the smaller electrode. It was expected that this change in welding procedure would influence the transition temperature. The welding schedule for the standard and modified tee-bend specimens follows:

	Standard tee bend	*Modified tee-bend*
Electrode class	E6010	E6010
Electrode diameter, in.	$^5/_{32}$	$^3/_{16}$
Average welding current, amp.	145	180
Average arc volts	25	27
Average welding speed, in./min.	2·8	4
Arc time, sec.	57	60
Length of weld increment, in.	2·7	4
Heat input, joules/in.	76,500	73,000

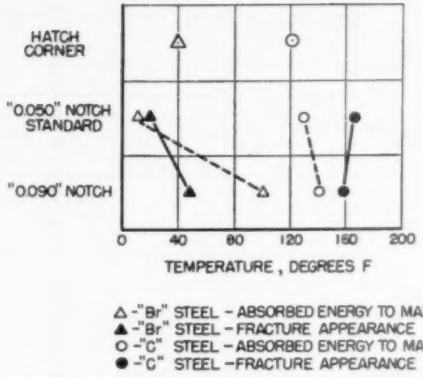


Fig. 12 Transition temperatures obtained for "Br" and "C" steels with Kinzel specimens with two different notch depths

A weldment was made from "Br" steel using the modified welding procedure. It was cut into standard-size specimens, $1^7/_8$ in. wide, and tested at various temperatures. The transition temperature for the "Br" steel obtained with the modified specimens was about 10° lower than for the standard tee-bend specimens, as is indicated by Fig. 13.

These tests showed that the change in the welding schedule had only a minor influence on transition temperature. This did not accomplish the desired increase in transition temperature, but, on the basis of the results, it was decided to use the modified welding schedule for tee-bend specimens of different widths.

Influence of Specimen Width on Transition Temperatures of Tee-Bend Specimens

Tee-bend specimens of "Br" and "C" steels were made in which the width was increased from $1^7/_8$ to 3

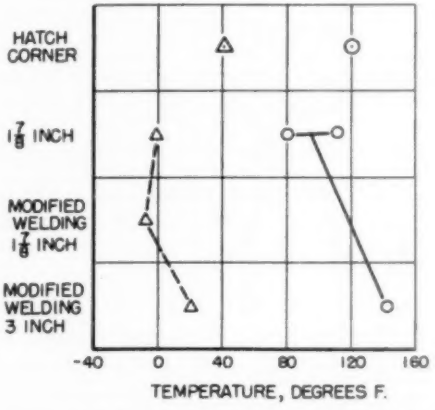


Fig. 13 Transition temperatures obtained for "Br" and "C" steels by standard and modified tee-bend specimens

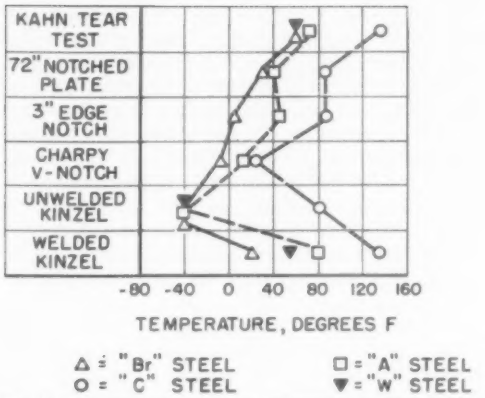


Fig. 14 Summary of transition temperatures obtained for "Br," "A," "W" and "C" steels by various tests

in. in an attempt to increase the transition temperature. The modified welding schedule was also used for this series of tests rather than the standard schedule. A comparative series of tests using specimens 3 in. wide and welded with the standard schedule might have been desirable to determine the influence of specimen width alone on transition temperature. However, the relatively small influence of the modified welding on the "Br" steel did not warrant these tests, since the supply of "C" steel was very limited.

The transition temperature of the "Br" steel using the modified tee-bend specimens (3 in. wide) was about +20° F., as shown in Fig. 13. This was decidedly higher than the 0° F. obtained previously with the standard tee-bend specimens of "Br" steel, but was still below the transition temperature of the "Br" steel hatch corner. The "C" steel, however, was influenced more by the modified welding and increased width than the "Br" steel. The transition temperature was 140° F., which is 20° higher than the transition temperature of the "C" steel hatch corner. These tests indicated that the transition temperature of "C" steel tee-bend specimens is more responsive to variations in specimen width than that of the "Br" steel.

TRANSITION TEMPERATURES OF "A" AND "W" STEELS DETERMINED BY KINZEL SPECIMENS

Along with the tests of the influence of changes of specimen design on transition temperature, it was decided to test two other steels with the Kinzel specimen. These steels were a semikilled steel "A" and a fully killed steel "W" (see Table 1 for compositions). Other tests with these steels showed transition temperatures which were between those of the "Br" and "C". Some of these are given in Fig. 14. Therefore, it was decided to check the behavior of the Kinzel specimen with these additional steels.

Standard Kinzel specimens were made from these steels and tested. The transition temperatures from these tests are compared with those obtained from the "Br" and "C" steels with Kinzel and other types of specimens in Fig. 14. They showed that the "A" and "W" steels had transition temperatures between those of steels "Br" and "C", as determined by the Kinzel specimen. This was in order with all previous work done with these steels. However, the welded Kinzel specimen showed greater differences in the transition temperatures of these steels than had been shown by other tests.

TESTS OF E6010 AND E6020 WELD METALS

Most of the welding for this investigation was done with E6010 electrodes. Since E6020 electrodes are often used in ship construction, the question arose regarding any difference in results which might occur if E6020 electrodes were used. Also, since the welded specimens had higher transition temperatures than unwelded specimens of the same design, it was decided to obtain information on the transition temperatures of the weld metals.

Influence of Weld Metal on Transition Temperature of Kinzel-Type Specimens

The welding schedule used for the previous series of specimens welded with E6010 electrodes, and that used for specimens welded with E6020 electrodes, are shown below for comparison:

	E6010	*E6020*
Electrode diameter, in.	5/16	5/16
Amperes	175	198
Arc voltage	27	33
Speed, in./min.	6	8 1/4
Arc time, sec.	40	29
Length of weld bead, in.	4	4
Heat input, joules/in.	44,750	44,750

As shown by this table, the heat input per inch of

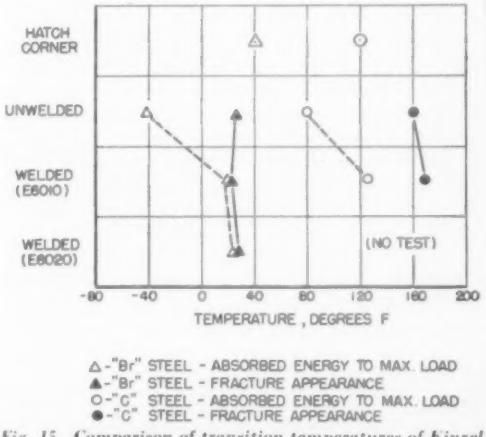

HATCH CORNER
UNWELDED
WELDED (E6010)
WELDED (E6020)
(NO TEST)
-80 -40 0 40 80 120 160 200
TEMPERATURE, DEGREES F
△-"Br" STEEL - ABSORBED ENERGY TO MAX. LOAD
▲-"Br" STEEL - FRACTURE APPEARANCE
○-"C" STEEL - ABSORBED ENERGY TO MAX. LOAD
●-"C" STEEL - FRACTURE APPEARANCE

Fig. 15 Comparison of transition temperatures of Kinzel specimens welded with E6010 and E6020 electrodes

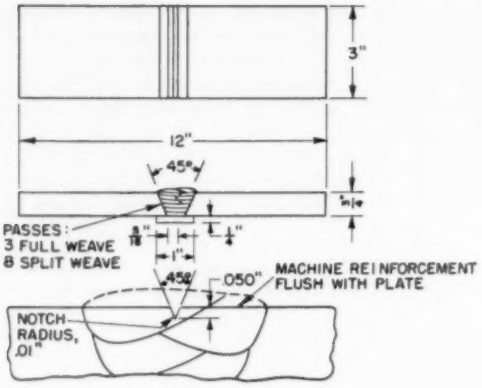


Fig. 16 All-weld-metal bend specimens (Kinzel type) having a multipass single-vee butt joint and a transverse notch

deposited weld metal was made the same for specimens welded with the two types of electrodes. This variable was controlled closely so that transition-temperature changes could be attributed to differences in type of weld metal rather than to other variables.

The transition temperatures for unwelded specimens of "Br" steel, and the standard Kinzel specimens of "Br" steel welded with E6010 electrodes and those welded with E6020 electrodes are shown in Fig. 15. The transition temperature of "Br" steel specimens having E6020 weld beads was 10° to 20° F. higher than for specimens having E6010 weld beads.

Tests were not made with "C" steel because only a small influence of E6020 weld metal on the transition temperature of "Br" steel was noted, and the stock of "C" steel was limited.

Transition-Temperature Studies of All-Weld-Metal Specimens

The design of the specimens used for these tests is illustrated in Fig. 16. The weld metal was deposited by $^5/_{32}$-in.-diameter Class E6010 and E6020 electrodes on "Br" steel in accordance with the requirements of the Navy Department, Bureau of Ships Interior Specification 46E3, dated Nov. 1, 1945. After welding, the weld reinforcement was machined flush with the plate surface, and a notch (Kinzel design) was cut in the weld metal transverse to the longitudinal direction of the specimen, as shown in Fig. 15. In most of the specimens, the root of the notch was in columnar grains of weld metal, but in some the root of the notch was in weld metal refined by heat from subsequent weld passes.

The specimens were tested in the manner described for the notched-bead bend specimens. Lower testing temperatures required for these tests were obtained by using liquid nitrogen and a heat exchanger in the cooling bath.

A comparison of the transition temperatures of the bead-welded and all-weld-metal notched-bend specimens is shown in Fig. 17. The change from ductile to brittle behavior for both E6010 and E6020 all-weld-metal specimens occurred at a lower temperature and covered a considerably wider range than for the welded notched-bead bend tests of "Br" and "C" steels. Welding with E6010 electrodes, however, produced lower transition temperatures with both kinds of specimens than welding with E6020 electrodes.

Before these results could be correlated, it was necessary to determine the cause for the wide transition-temperature range for the all-weld-metal specimens. The microstructure of several representative specimens taken from the weld metal transverse to the notch were studied. Variations in the grain structure at the root of the notch were found to correlate with the wide transition range. Specimens having the notch cut in a heat-refined grain structure, as shown by Fig. 18, showed higher energy absorption and ductility for a given temperature than those having the notch cut in the coarse columnar weld metal, as shown by Fig. 19. A fine-grain structure at the root of the notch gave lower transition temperatures than a coarse-grain structure at that location. Figure 20 further illustrates the significant influence that grain structure has on the fracture or behavior of notched-bend specimens. This all-weld-metal bend specimen was notched in a heat-refined grain structure, but actually failed in the unnotched coarse-columnar weld metal midway between the notch and the base metal.

This suggests that at low temperatures the coarse-

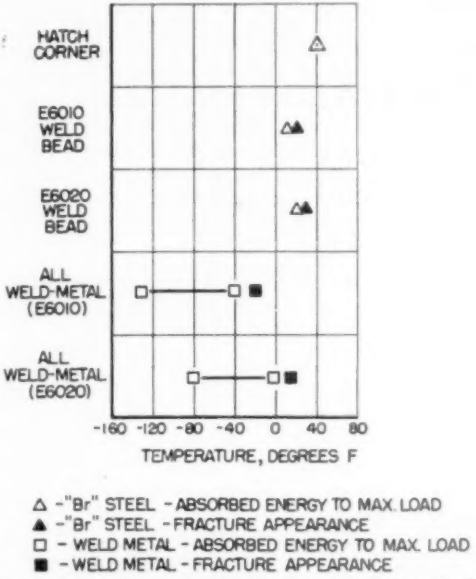

HATCH CORNER
E6010 WELD BEAD
E6020 WELD BEAD
ALL WELD-METAL (E6010)
ALL WELD-METAL (E6020)
-160 -120 -80 -40 0 40 80
TEMPERATURE, DEGREES F
△ -"Br" STEEL - ABSORBED ENERGY TO MAX. LOAD
▲ -"Br" STEEL - FRACTURE APPEARANCE
□ - WELD METAL - ABSORBED ENERGY TO MAX. LOAD
■ - WELD METAL - FRACTURE APPEARANCE

Fig. 17 Comparison of transition temperatures of standard Kinzel specimens of "Br" steel welded with E6010 and E6020 electrodes with those obtained from all-weld-metal specimens made with E6010 and E6020 electrodes

columnar structure of "as-deposited" weld metal without a notch may be more susceptible to fracture than the heat-refined weld metal containing a notch. In notched-bead bend specimens, fracture opens up in the weld bead at the root of the notch, and becomes large in the weld area before it does in other parts of the specimen. The coarse-grain weld metal (along with other factors), in all probability, contributes to this behavior of the specimens. More work is in progress on the initiation and propagation of fracture in these specimens, and will be reported in a later publication.

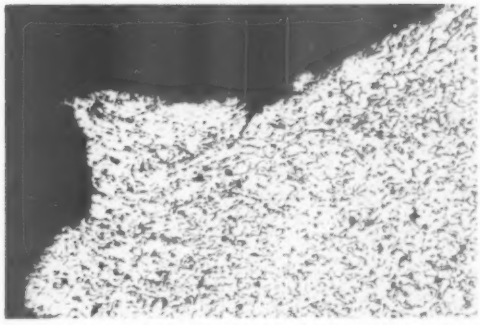
Effects of Thermal Treatments on Kinzel Specimens of "Br" and "C" Steels

Some of the hatch-corner specimens were given a stress-relieving treatment after welding. In others, preheats were used before welding. Both of these thermal treatments increased the energy absorption of the specimens and lowered the transition temperature. Other experience has shown that preheating and post-heating weldments improve their properties. Therefore, it was decided to study the influence of various thermal treatments on the transition temperatures of the "Br" and "C" steels as determined by the Kinzel-type specimen.

Preparation and Welding of Specimens

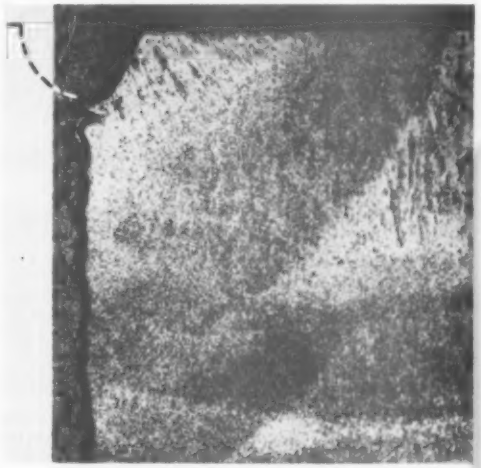
The specimens were prepared, welded and tested

Mag. 10 ×

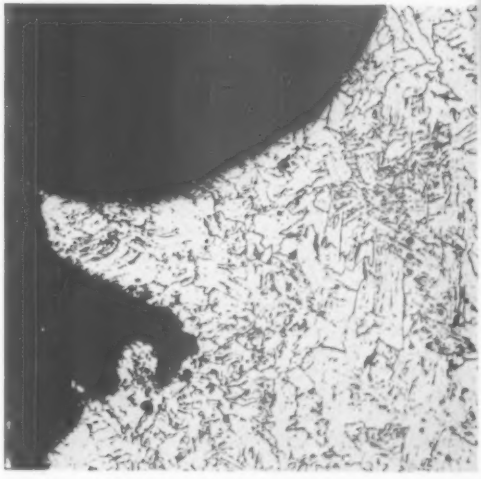


Mag. 100 ×

Fig. 18 Section of an all-weld-metal notched bend specimen having the root of the notch in the refined grain structure of the as-deposited E6010 weld metal. Compare with Fig. 19



Mag. 10 ×



Mag. 100 ×

Fig. 19 Section of an all-weld-metal notched bend specimen having the root of the notch in the coarse columnar structure of the as-deposited E6010 weld metal. Compare with Fig. 18

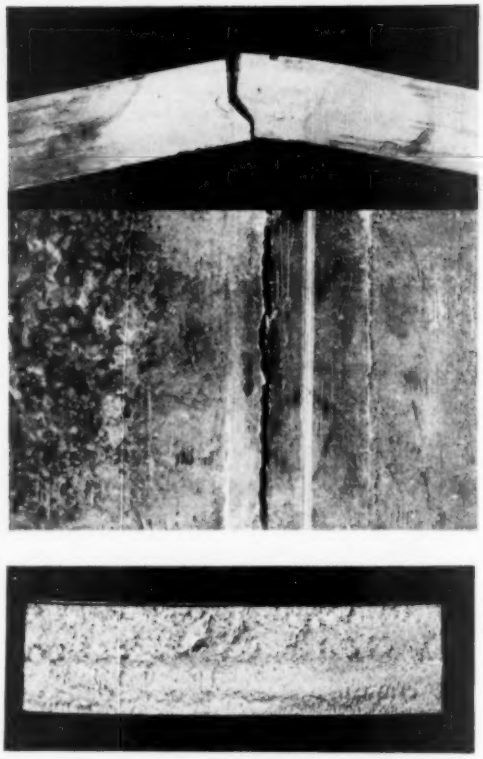


Fig. 20 All-weld-metal (E6010) bend specimen tested at − 150° F. showing a fracture in the coarse-grain structure of the weld metal adjacent to the machined notch

according to standard practices for Kinzel specimens, except for the preheats and postheats used.

The cooling rates of the specimens were determined on typical specimens welded with various preheats. This was done so that the influence of preheat on the cooling of the specimen could be correlated with: (*a*) hardness of the heat-affected metal around the weld; and (*b*) the performance of the specimen when tested at various temperatures. To obtain these rates, a small hole was drilled from the bottom side of a specimen and a chromel-alumel thermocouple was welded in the hole shown in Fig. 21. The cooling curves for the first minute were recorded on an automatic Speedomax recorder. After preheating and welding, the specimens were permitted to cool in air at 70° F. The cooling curves for the various preheats used are shown in Fig. 22.

Effects of Various Preheats on "Br" and "C" Steels

Preheats of 10°, 70°, 150°, 250° and 400° F. were used on groups of specimens made of both "Br" and "C" steels. One group of each steel was welded at 70° F., and then postheated at 1150° F.; and one of

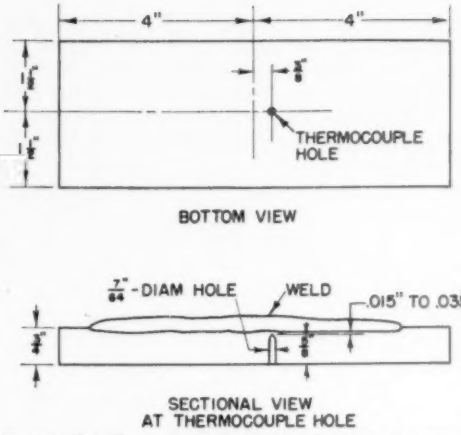


Fig. 21 Details of specimen used to obtain cooling curves of Kinzel specimens

"Br" steel was preheated at 400° F., and then postheated at 1150° F.

A summary of the effects of these treatments on the transition temperatures of the steels is given in Figs. 23 and 24. The transition temperature remained about the same for each steel when welded at 10° and 70° F. There were some variations as the preheating temperature was increased, but, as shown by the figures, preheating generally lowered the transition temperature of the specimen. There appeared to be very little effect from the postheat treatment that was not produced by the 250° F. preheating on the two steels. On the "Br," the 400° F. did not give so much

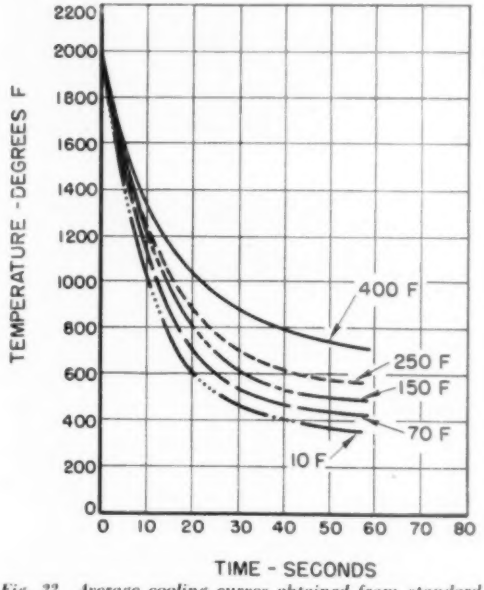
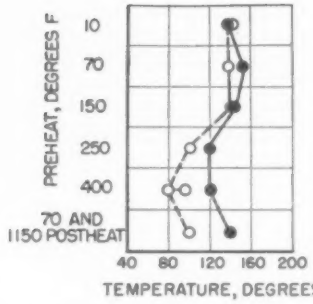


Fig. 22 Average cooling curves obtained from standard Kinzel specimens preheated to various temperatures



O - "C" STEEL-ABSORBED ENERGY TO MAXIMUM LOAD
● - "C" STEEL- FRACTURE APPEARANCE

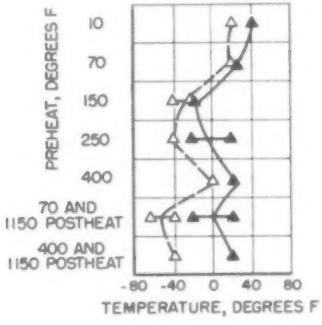
Fig. 23 Transition temperatures obtained from Kinzel specimens of "C" steel given various preheats and postheats

improvement as 250° or the 1150° F. postheat. This was a reversal of what might be expected on the basis of results obtained on the "C" steel. Further investigation of this apparent anomaly is being conducted. Preheats of 500° and 600° F. are also being tried on "C" steel to determine if a similar reversal will result on this steel at a higher preheat.

Effect of Preheat and Postheat on Hardness of Welds and Heat-Affected Zones of Welds

Hardness surveys were made across the welds and heat-affected areas of the specimens which were preheated and postheated at various temperatures to correlate with results obtained from the transition-temperature studies.

A summary of the results of these tests is given in Figs. 25 and 26. These results show that the higher preheats and the postheats reduced the hardness of the weld and heat-affected areas of the specimens. The greatest reduction in hardness resulted from the 1150° F. postheat treatment. There was considerable differ-



Δ - "Br" STEEL-ABSORBED ENERGY TO MAXIMUM LOAD
▲ - "Br" STEEL- FRACTURE APPEARANCE

Fig. 24 Transition temperatures obtained from Kinzel specimens of "Br" steel given various preheats and postheats

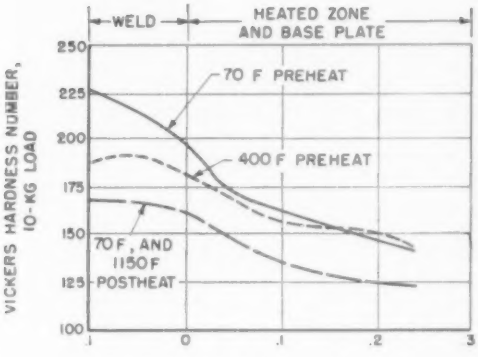


Fig. 25 Average hardness curves on welds, heat-affected zone and base material of Kinzel specimens of "Br" steel given various preheats and postheats

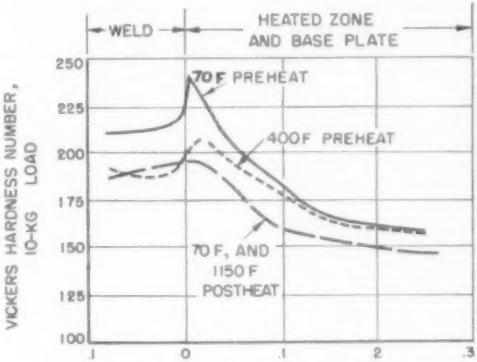


Fig. 26 Average hardness curves on welds, heat-affected zones and base material of Kinzel specimens of "C" steel given various preheats and postheats

ence in the "Br" and "C" steels which was probably caused by the difference in carbon content of the two steels. These results generally correlate with lowering of the transition temperatures, as previously discussed, but do not necessarily have a direct bearing upon lower transition temperature. That is, the preheat and postheat treatments may have produced other effects along with changing the hardness. These effects are in all probability responsible for the changes in performance and transition temperature of the specimen. A possible change may have been a reduction in the number of microcracks in the weld metal as a result of slower cooling.

OBSERVATION OF FRACTURE INITIATION IN SPECIMENS STUDIED

During the testing of many of the Kinzel, Lehigh and notched-tension specimens it was noted that the cracks appeared to start at the center of the specimens in the weld area. These cracks often grew to as much

as $^{3}/_{4}$ in. long and $^{1}/_{16}$ in. wide before the specimen reached maximum load. It was not definite from these observations just when and where the initial cracks started, that is, in the weld, or heat-affected zone of the base material, but there was no mistake about the fact that they started in the weld area and grew to appreciable size before maximum load on the specimen was reached.

As a result of these observations, extensive work was started to determine more exactly where and when the fractures start, and how they propagate. The thought was that such a study should furnish important information regarding the influence of welding upon the performance of these steels when tested by this type of specimen. The work is now in progress and will be reported in a later paper.

GENERAL DISCUSSION

As stated previously, the over-all objective of this investigation was to evaluate various types of small bend and tension specimens of welded ship steels for their suitability in: (1) determining the transition temperature (ductile to brittle behavior) of welded steels; and (2) indicating the performance of large weldments. For (2), it was necessary to adopt a secondary standard, so the actual objective was to obtain a small welded specimen which would give the same transition temperature as the large hatch-corner weldments of the same steels tested at the University of California. The many questions that are raised by the use of the hatch corner as a secondary standard, and any limitations that are thus imposed on using these results to predict probable behavior in large welded structures, were not a part of this investigation.

On the basis of results obtained from this investigation, all three bend specimens and the tension specimen showed that "Br" steel had a lower transition temperature than the "C" steel, and absorbed more energy at low temperatures. This correlates well with the results of many other types of test specimens (some containing welds and some without welds) including the hatch-corner tests used to study these steels.

The results also generally showed that unwelded specimens had lower transition temperatures than welded specimens. How much the unaffected stock on both sides of the weld zone (where the sharp crack forms) contributes to the over-all performance and thus affects the location of the transition temperature is not brought out. This finding also agrees with results obtained by other investigators. Therefore, it may be concluded that any one of the specimens used in this investigation, and others used by other investigators, may be used to show relative notch behavior of these steels, welded or unwelded.

The transition temperatures obtained from the hatch-corner specimens for "Br" and "C" steels were not duplicated for both steels by any one of the small test specimens, or by any modification of any one of these specimens. Changes in width, notch depth and welding procedure shifted the transition temperature either up or down, but this usually changed the transition temperature more for one steel than for the other. Therefore, it appears unlikely that any one type or design of small specimen will be easily developed to give the same transition temperature for "Br" and "C" steels, or other steels, which would be obtained by testing hatch-corner specimens or some other large weldment. However, small specimens are thought to be useful in the evaluation of steels for service, if one were consistently used until test results could be correlated with service performance of the steels in welded structures.

Tests with E6010 and E6020 weld metals showed that E6010 gave slightly better performance. All-weld-metal specimens gave very low transition-temperature ranges, but the transition temperature depended greatly upon the location of the notch; i.e., whether it was in columnar grains or in the small refined grains of multipass welds. A striking example of this was cited which emphasizes the need for more study of the weld metal, and its influence upon the performance of weldments.

Some work in this direction was done by preheating and postheating the welds of bend specimens of "Br" and "C" steels. Judged by transition temperatures, the preheating at 400° F. was found to produce the greatest improvement in "C" steel of the preheats used, but did not in "Br" steel. It also gave as much improvement as the postheat treatment of 1150° F. on "C" steel. The hardness studies showed that the hardnesses of the weld and heat-affected zones were lowered by the thermal treatments. The lower hardness, generally, correlated with improvements in performance of the specimen. However, little is known about the cause, or causes, of improvements in the weld and heat-affected zones which were produced by the thermal treatment. Results of some current work being done on weld metals indicate that this treatment may have reduced the number of microcracks in the weld metal. Structure has been shown to be important, and hydrogen is doubtless another agent which affects the behavior. On this basis, it appears that more study of the weld metal could provide useful information.

Observations made during this investigation show that the weld metal affected the behavior of the specimen to a marked degree. The specimens (except tee-bend) have columnar weld metal at the root of the machined notch which appears to open up a sharp crack very early in the test, so that the heat-effected zone, and, later, the unaffected base metal, is exposed to an additional sharp central notch. On this account, it is not clear just how the heat-affected zone, presumably the major welding effect, compares with the base metal, because they are not tested under the same conditions, though the machined notch subjects them initially to very similar stresses. However, if the carbon content or hardness of the heat-affected zone were greater, it is presumed that the crack would start there, in preference to the weld metal, and, indeed, it is

sometimes difficult with ship steel to determine just where the crack initiates and whether very small surface tears at the root of the notch are significant as crack initiators.

On the whole, it is clear that the unaffected stock has a controlling effect on the course of the load-deflection curve, which is the basis of the transition-temperature curve. Tests on the unwelded samples show that the steel can deform at the root of the machined notch under conditions which initiate and propagate a crack in the welded sample. Thus, we may regard the transition temperature of the Kinzel specimen as the temperature at which the sharp central crack reinforces the machined notch sufficiently to change the normal ductile behavior of the steel, at that temperature, to brittle behavior. There is evidence that the hatch-corner specimens, due to weld failures, were subjected to a similar stress condition. Thus, a close examination of the behavior of the Kinzel type of specimen when made of this ship steel suggests that it is a test of the notch behavior of weld metal and steel, principally the latter, and, on this basis, the general correlation with other tests of notch behavior of the steel seems reasonable.

SUMMARY STATEMENTS

1. A literature survey was made to catalog and appraise the various kinds of tests used to study strength, ductility and transition temperatures of welded joints in structural steels. On the basis of this survey, three bend-test specimens and one notched-tension specimen (Lehigh, Kinzel, tee-bend and tension) were selected for study. Results obtained with these tests were correlated with those obtained from full-scale hatch-corner specimens tested at the University of California.

2. The initial studies with these tests showed that all of the specimens rated the test steels in the same order of performance as did hatch-corner specimens and other specimens used by other investigators, i.e., "Br" steel had a lower transition temperature than "C" steel; "A" and "W" steels were between "Br" and "C" in transition temperature.

3. The Kinzel specimen and the tee-bend specimen gave transition temperatures for "Br" and "C" steels which were closer to those of the hatch-corner tests than those obtained by other specimens studied.

4. Modifications of the Kinzel specimens and tee-bend specimens were studied in an attempt to match the transition temperatures obtained by the hatch-corner specimens on "Br" and "C" steels. Generally, the modifications of the specimens shifted the transition temperatures of the two steels up or down, depending upon the modification. However, the same change in specimen design or procedure of producing the specimens did not produce shifts of similar magnitude in the transiton temperatures of the "Br" and "C" steels. Therefore, it appeared quite unlikely, on the basis of information available, that any one type or design of small specimen will give the same transition temperature for "Br" and "C" steels, and other steels, that was or might be obtained by large specimens, such as the hatch-corner specimens.

5. Tests showed that Kinzel specimens of "Br" steel had a slightly higher transition temperature (10° to 20° F.) when E6020 electrodes were used instead of E6010 electrodes.

6. Transition-temperature studies of E6010 and E6020 weld metals were made with all-weld-metal specimens similar in design to Kinzel specimens and tested by bending. They showed that the transition temperatures of these weld metals were much lower than those obtained with standard (bead on plate) specimens. The transition temperature of the E6010 weld metal ranged from −130° to −40° F., and varied with the location of the notch; i.e., if the notch was in columnar structure, the transition was high, and if it was in the refined structure of the weld metal, it was low. The transition temperature of E6020 weld metal ranged from −70° to 0° F.

7. Various tests using preheats and postheat treatments of Kinzel specimens of "Br" and "C" steels showed that, generally, the preheating above 150° and up to 400° F. lowered the transition temperatures of the two welded steels. No important gain was obtained by using 1150° F. postheat which was not obtained by 400° F. preheat.

8. Hardness studies across weld joints which were preheated and postheated showed that the higher preheats of 400° F. and the postheat treatments generally lowered the hardness of the weld metal and heat-affected zones of the weld. Lower hardness generally correlated with better performance of the specimen; however, better performance is not necessarily related to lowering of the hardness of the heat-affected zone.

ACKNOWLEDGMENT

We wish to acknowledge work done on this project by other members of the Battelle staff, and, in particular, that done by R. W. Bennett and M. Forman, former members. We wish also to express our appreciation for guidance in this investigation to S. L. Hoyt, Technical Advisor, and C. E. Sims, Assistant Director.

We are indebted to Dr. Finn Jonassen, Technical Director, Committee on Ship Steels, National Research Council, and the Project Committee appointed through his office.

Appendix A

PREPARATION OF TEST SPECIMENS

The preparation of the welded specimens involved three steps: (1) preparation of plates for welding; (2) welding; and (3) machining before testing. For certain tests, specimens were preheated and postheated.

Plate Preparation

Plates, 3 x 12 in. (except in special cases described later), were used for the bend specimens and the test section of the tension specimens which had longitudinal welds and transverse notches. (Kinzel, Lehigh and tension specimens were shown by Figs. 1, 2 and 5). They were saw cut rather than flame cut so that no heat-affected metal would be along the edges of the specimens.

The plates for the tee-bend test were flame cut to the size shown in Figs. 3 and 4. The heat-affected metal along the edges of these specimens was removed by machining after welding.

The direction of rolling for all specimens was parallel to the longitudinal direction of the finished specimen, as shown in the figures.

Table A-1—Welding Conditions Used for the Bend Test Specimens

	Type Test		
Welding Details	*Lehigh*	*Tension and Kinzel*	*Tee bend*
Electrode class	E6010	E6010	E6010
Electrode diameter, in.	3/16	3/16	5/32
Average welding current, amp.	175	175	145
Average arc volts	27	27	25
Average welding speed, in./min.	10	6	2.8
Length of weld bead, in.	10	4	2.7
Length of electrode per inch of weld	0.78	1.4	3.6
Initial plate temperature, ° F.	75	75	75
Cooling medium	Air	Air	Air

The plate surfaces were grit blasted prior to welding to remove mill scale, rust or other surface contaminators.

Welding Procedures

A summary of the welding conditions used for each of the test specimens is given in Table A-1. Automatic welding was used for all specimens except for the initial tee-bend test specimens. Automatic welding was used for tee-bend specimens later in the investigation.

All specimens were welded at room temperature (70°–80° F.) except a few which were preheated and will be discussed later. After welding, they were set endwise on asbestos and cooled in air to room temperature. (A few of the specimens were given various postheat treatments which will be discussed in later sections.) All of the specimens (except those postheated) were aged for eight days at room temperature before testing. During this period, they were machined to the final dimensions for testing.

Machining

The test specimens were machined to the dimensions shown in Figs. 1 to 5 with a few exceptions discussed in other sections of the paper. The sides of the specimens were finished by grinding to aid in taking accurate lateral measurements before and after testing. The transverse notches in both the longitudinally welded and transversely welded bend specimens were made with a fly cutter to accurately obtain the prescribed root radius. The depths of the notches were changed in a few special tests.

In the weldment for the tee-bend test, the vertical leg was flame cut to size so that it would fit a standard bending-jig guide. To insure uniformity for this test, the weldment was saw cut with the crater from one weld increment and start of the next increment centered in the test specimen, as shown in Fig. 4. Some variations of the tee-bend test were studied which were discussed in other sections of the paper.

The tension specimen, as shown in Fig. 5, had a notch like that of a Kinzel-type specimen. The width of the test section of this specimen was reduced to 2¾ in. to accommodate the testing equipment and to prevent the possibility of failure away from the notched section. Adapter bars were welded to the ends of the project steel, before machining, to reduce the amount of test steels required.

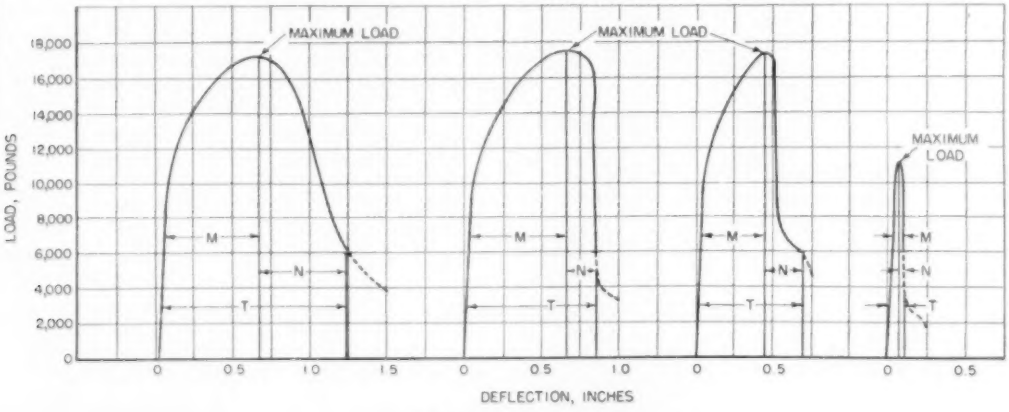


Fig. A-1 Schematic diagrams of typical load-deflection curves

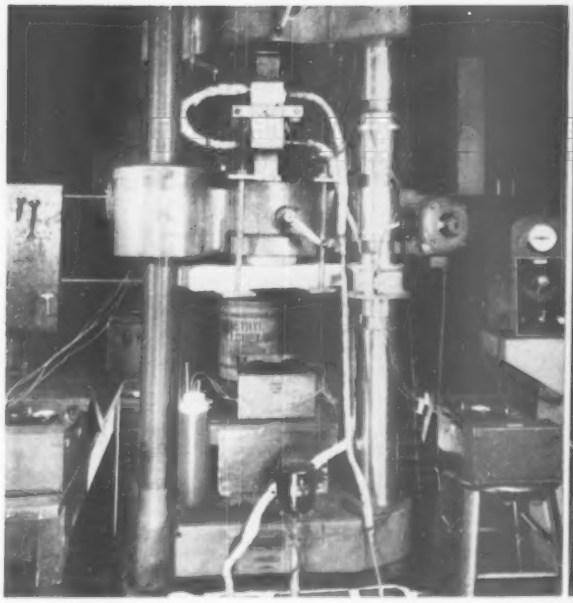


Fig. A-2 Apparatus used for testing tension specimens

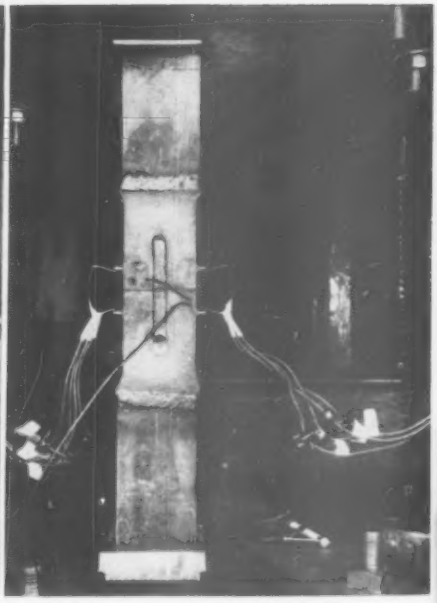


Fig. A-3 Front view of tension specimen in testing machine with strain gages attached

TESTING PROCEDURE

It was necessary either to heat or cool the test specimens to various temperatures and to maintain the temperature during testing to determine the temperature at which the specimen exhibited a transition from ductile to brittle behavior. A special setup was made for the bend test and another for the tension tests.

Bend Tests

Both the bending jig and the test specimens were immersed in an agitated liquid and maintained at the desired temperature for at least 15 min. before applying the load. A mixture of alcohol and dry ice was used for all temperatures below about 80° F. Temperatures ranging from about 80° to 200° F. were attained by using water heated with resistance-immersion units. Above 200° F., a water-soluble quenching oil was used with the immersion heaters to attain the desired temperature.

The dimensions of the bending jigs used for testing the various types of specimens are schematically illustrated in Figs. 1 to 5.

All of the specimens were loaded at 1 in. per minute free displacement of the movable platen of the testing machine. The load was usually applied until the specimen fractured, but, if the specimen did not fail, loading was continued until the load reached a maximum and then dropped to 6000 pounds, or until the limit of the testing apparatus was reached. A load-deflection curve, as illustrated in Fig. A-1, was made for each specimen.

Tension Tests

The tension specimens were heated or cooled by heat-exchanger blocks clamped tightly against the surfaces of the test specimens, as shown in Fig. A-2. A shallow groove was machined in one block to accommodate the weld bead. Cooling on the edges of the testpiece, except where the strain gages were attached, helped to maintain a constant temperature across the entire specimen. The desired temperature was obtained by pumping a cooled or heated solution through the heat

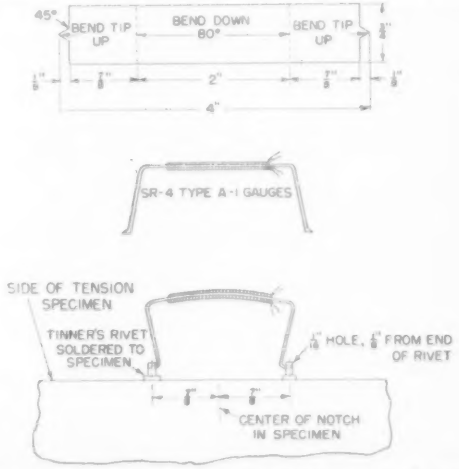


Fig. A-4 Details of clip-type compensating strain gage showing attachment to tension specimen. (Developed at University of California)

exchanger. The specimen temperature was measured by a copper-constantan thermocouple welded to the specimen $^1/_8$ in. below the surface adjacent to the bead and slightly above the notch, as shown in Fig. A-3.

Tests showed that, at a temperature of −80° F., there was only an 8° difference in temperature from the center to the outer edge at the notch. This difference became less as the temperature was raised. At about 50° F., the specimen temperature was completely uniform.

The tension specimens were pulled in a 200,000-lb. capacity Baldwin-Southwark hydraulic testing machine. The moveable platen traveled at the rate of 0.02 in. per minute. The amount of energy required to break the specimen was obtained from load-deflection curves plotted from strain-gage measurements. Details of the clip-type compensating strain gages are shown in Fig. A-4. (This method of measuring strain in tension specimens was obtained from the Staff of the Engineering Materials Laboratory at the University of California.) The clips were fastened to tinner's rivets which were soft soldered to each side of the test specimen, as shown in Figs. A-3 and A-4. The leads from the SR-4 strain gages were connected to two Baldwin strain-gage indicators. The indicator readings were taken at successive load increments until the specimen failed. The load-elongation curves were plotted from these readings.

Axial Tension Impact Tests of Structural Steels

The transition temperature of killed steels decreases with decreasing initial energy. Rimmed and semikilled steels are little affected in this way

by W. H. Bruckner and N. M. Newmark

Abstract

Supplementary tension impact tests were made with specimens of two killed steels and a rimmed steel, at different levels of initial energy. The specimens were of the standard size and shape used in previous tests reported in a paper by the same authors published in the JOURNAL for February 1949. The new data show, as did the previous data, that for the killed steels the transition temperature decreases with decreasing initial energy, but for the rimmed steel there is little change in transition temperature with a change in initial energy of the impact.

Charpy impact tests were made with specimens of a semikilled steel which showed in the previous tests a considerable change in transition temperature when tested in axial tension impact. Both V-notch and keyhole-notch specimens were tested, but little effect was found for either type of specimen; both showed practically no change in transition temperature with change in initial energy.

W. H. Bruckner is Research Asst. Prof. of Metallurgical Engineering in the Dept. of Mining and Metallurgical Engineering. **N. M. Newmark** is Research Prof. of Structural Engineering, Dept. of Civil Engineering, University of Illinois, Urbana, Ill.

A supplement to the paper entitled "Axial Tension Impact Tests of Structural Steels," published in THE WELDING JOURNAL, February 1949, pp. 67-s to 88-s.

Scheduled for presentation at the Thirtieth Annual Meeting, A.W.S., Cleveland, Ohio, week of Oct. 17, 1949.

INTRODUCTION

THIS paper supplements a previous report by the authors, published in THE WELDING JOURNAL for February 1949. The details of the specimens and testing technique are described in the earlier paper. Additional tensile impact tests were made on specimens of steels as follows: a rimmed steel RR, as-rolled; a killed steel RK, as-rolled; and killed steel G, as-rolled. The G steel is one of the Ship Structure Committee Project steels. Charpy V-notch impact tests, with initial energies of 220 and 110 ft.-lb., were also made on specimens of semikilled steel A, as-rolled. A series of Charpy impact tests was also made with a keyhole notch-type specimen of steel A. For this series of tests three different initial energy levels were employed, i.e., 220, 110 and 45-ft.-lb.

ACKNOWLEDGMENT

This work has been performed as part of a cooperative research contract between the Engineering Experiment Station of the University of Illinois, and the Office of Naval Research, under Contract N6 onr-71, Task

Table 1S—Chemical Analyses of Steels

Steel	Kind of steel	Treatment	Per cent by weight of element noted											
			C	*Mn*	*P*	*S*	*Si*	*Al*	*Ni*	*Cu*	*Cr*	*Mo*	*Sn*	N_2
A	Killed	As-rolled	0.26	0.50	0.012	0.039	0.03	0.012	0.02	0.03	0.03	0.006	0.003	0.004
G	Killed	As-rolled	0.20	0.86	0.020	0.020	0.19	0.045	0.15	0.15	0.04	0.018	0.012	0.006
RR	Rimmed	As-rolled	0.27	0.33	0.008	0.025	0.01	...	..	..	..	...	...	0.006
RK	Killed	As-rolled	0.23	0.47	0.008	0.029	0.16	...	..	..	..	...	...	0.008

Table 2S—Summary of Transition Temperatures

Series	Steel	Specimen type	Initial energy, ft.-lb.	——Estimated transition temperature, ° F. from:—— Impact energy	Reduction of area	Reduction area, 15%	Impact energy-fracture area
1	E	A	220	115	110	110	120
1	G	A	220	70	50	20	50
1	Dr	A	220	50	50	40	50
1	Dn	A	220	15	50	25	50
3	E	B	220	125	...	110	...
		C	220	90	...	75	...
		D	220	100	100	90	...
4	E	E	220	130	130	130	140
		F	220	140	140	130	150
		G	200	150	150	145	160
		H	220	130	130	120	135
5	E	B (standard)	220	120	125	105	140
			110	115	115	105	120
			45	120	125	105	115
			33.8	110	115	110	110
6	A	B (standard)	220	105	110	95	110
			110	85	85	80	90
			45	80	75	70	80
6	C	B (standard)	220	110	115	110	115
			110	110	115	110	110
			45	110	110	100	110
7	Dr	B (standard)	220	55	55	45	55
			110	20	25	15	25
			45	20	20	15	20
7	Dn	B (standard)	220	60	55	45	60
			110	30	30	20	35
			45	15	15	10	15
8	G	B	220	60	50	40	60
			110	30	35	20	35
			45	20	20	15	20
9	RR	B	220	110	110	110	110
			110	100	100	95	110
			45	100	95	90	105
10	RK	B	220	60	60	60	65
			110	40	40	40	45
			45	20	20	20	30

Order V. All work on this task is under the supervision of Prof. Newmark. The tests reported herein were performed under Prof. Bruckner's direction, and the test data were compiled by him.

The authors are indebted by Dr. R. A. Hechtman, formerly Special Research Engineer in Civil Engineering, for his services in scheduling the production of specimens for test and for many valuable suggestions.

MATERIALS

All of the specimens were made from $^3/_4$-in. plate stock. Table 1S gives the chemical analyses of the four steels for which new impact test data are reported herein.

PROCEDURE

The tensile impact tests were made with the standard Type B specimens of steels G, RR and RK. The standard specimen has a semicircular notch of 0.039 in. radius, a root diameter of 0.294 in., an outside diameter of 0.625 in. and a total length of about 4 in. The test were made at three different levels of initial energy i.e., 220, 110 and 45 ft.-lb.

The Charpy V-notch impact tests were made with standard A.S.T.M. 0.394-in. square specimens. The V-notch was milled perpendicular to the rolled surface of the plate from which the specimens were cut. Two initial energy levels, 220 and 110 ft.-lb., were used. For each initial energy level the temperature of test was varied to give a complete impact energy-temperature curve above, below and in the transition range. For each temperature of test four specimens were tested,

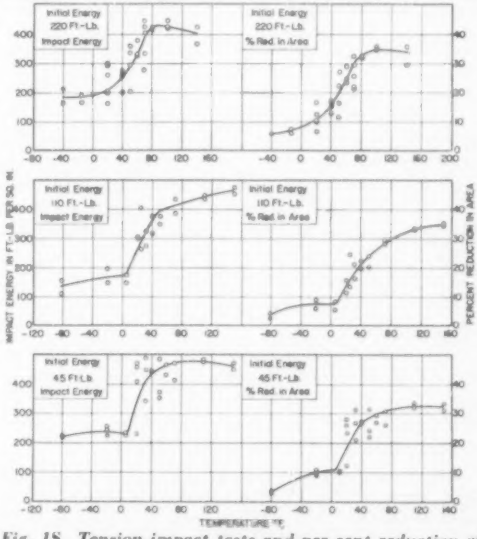
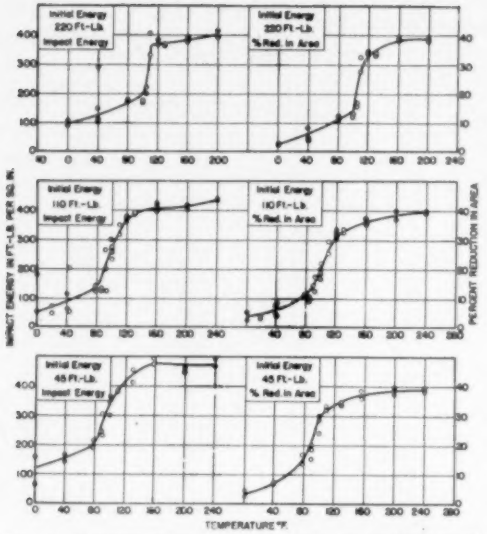

Initial Energy 220 Ft.-Lb. Impact Energy
Initial Energy 220 Ft.-Lb. % Red. in Area
Initial Energy 110 Ft.-Lb. Impact Energy
Initial Energy 110 Ft.-Lb. % Red. in Area
Initial Energy 45 Ft.-Lb. Impact Energy
Initial Energy 45 Ft.-Lb. % Red. in Area
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION IN AREA
TEMPERATURE °F.

Fig. 1S Tension impact tests and per cent reduction of area, Series 8, Type B specimens of killed steel G, as-rolled; 220, 110 and 45 ft.-lb. initial energy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Initial Energy 110 Ft.-Lb. Impact Energy
Initial Energy 110 Ft.-Lb. % Red. in Area
Initial Energy 45 Ft.-Lb. Impact Energy
Initial Energy 45 Ft.-Lb. % Red. in Area
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION IN AREA
TEMPERATURE °F.

Fig. 2S Tension impact tests and per cent reduction of area, Series 9, Type B specimens of rimmed steel RR, as-rolled; 220, 110 and 45 ft.-lb. initial energy

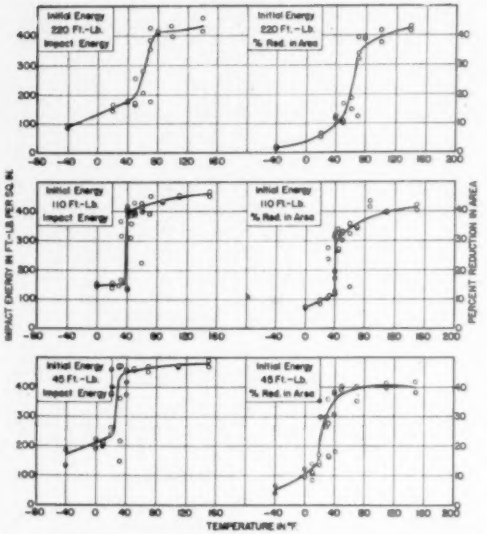
Initial Energy 220 Ft.-Lb. Impact Energy
Initial Energy 220 Ft.-Lb. % Red. in Area
Initial Energy 110 Ft.-Lb. Impact Energy
Initial Energy 110 Ft.-Lb. % Red. in Area
Initial Energy 45 Ft.-Lb. Impact Energy
Initial Energy 45 Ft.-Lb. % Red. in Area
IMPACT ENERGY IN FT.-LB. PER SQ. IN.
PERCENT REDUCTION IN AREA
TEMPERATURE IN °F.

Fig. 3S Tension impact tests and per cent reduction of area, Series 10, Type B specimens of killed steel RK, as-rolled; 220, 110 and 45 ft.-lb. initial energy

two (A) specimens from one side of the $^3/_4$-in. thick plate, and two (B) specimens from the opposite side of the plate. The specimens were machined with one side within 0.010 in. from the nearest rolled surface, thus the four specimens tested at each temperature represented on the average a test of practically the full $^3/_4$-in. plate thickness.

The Charpy keyhole-notch impact tests were made in the same manner as described above for the Charpy V-notch impact tests. The keyhole-notch specimen was a standard A.S.T.M.-type specimen. Initial energy levels of 220, 110 and 45 ft.-lb. were employed for the three corresponding test series.

DATA OBTAINED

The data for the tension impact tests are available on request in tabular form. The corresponding impact energy-temperature curves and per cent reduction of area-temperature curves are given in Figs. 1S, 2S and 3S. An estimate of the transition temperatures based on various criteria is given in Table 2S, which includes Table 11 of the previous paper as well as new data. These data are compared with the prior data in Fig. 4S in which are plotted the transition temperatures vs. the initial energy of impact.

The data from the Charpy V-notch impact tests are also available in tabular form on request. The estimated transition temperatures are given in Table 3S. The curves of impact energy vs. temperature corresponding to these data are given in Fig. 5S.

The data from the Charpy keyhole-notch impact tests are available in tabular form on request. The estimated transition temperatures are given in Table 4S. The curves of impact energy vs. temperature corresponding to these data are given in Figs. 6S and 7S.

DISCUSSION

The reproducibility of tension impact data for killed steel G as-rolled, as shown in Fig. 1S, is lower than for the other steels, as shown by the wider scatter of values in the transition range. This scatter of values was also indicated for the Type A specimens of this steel, in Fig. 3 of the previous paper. However, the transition temperature of steel G is about as sensitive to a change in initial energy as the other killed steels, as shown in Table 2S, and Fig. 4S.

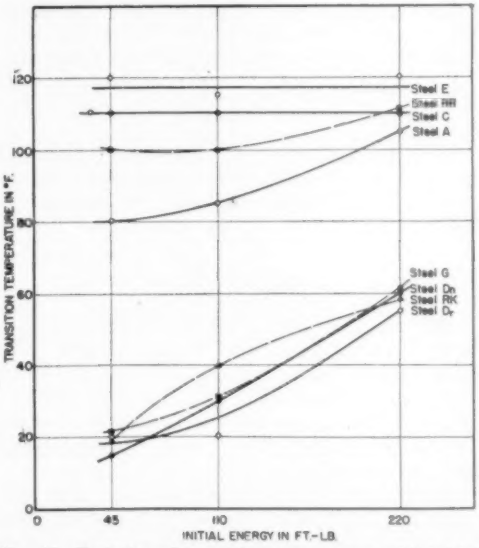

Fig. 4S Variation of transition temperature with initial energy for several steels

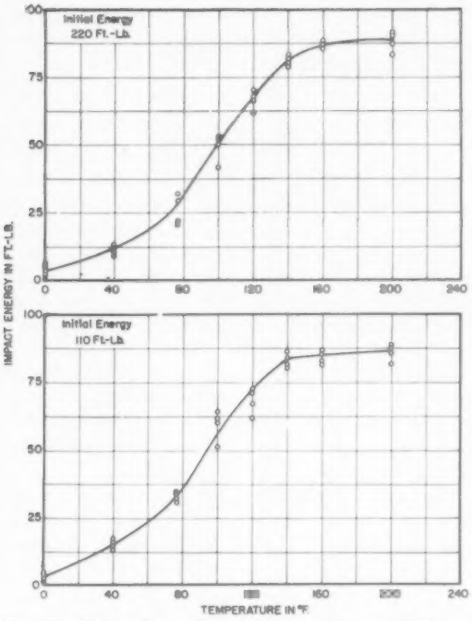

Fig. 5S Charpy V-notch impact tests of semikilled steel A, as-rolled; 220 and 110 ft.-lb. initial energy

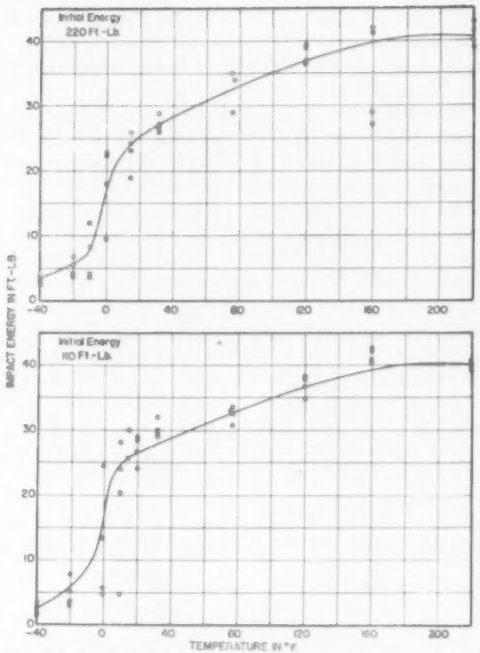

Fig. 6S Charpy keyhole-notch impact tests of semikilled steel A, as-rolled; 220 and 110 ft.-lb. initial energy

The rimmed, as-rolled steel RR, Series 9, had a transition range which paralleled that of the rimmed steel E and showed a similar insensitivity to a change in initial energy. However, the transition temperature of steel RR based on a reduction of area of 15% showed a slight but consistent downward trend with decreasing initial energy, which was not the case for steel E.

The killed, as-rolled steel RK, Series 10, exhibited a behavior comparable to that of similar killed steel Dr and Dn and of the semikilled steel A. The transition temperatures for steel RK decreased with decreasing initial energy. The test values were almost the same as those for steel Dn at equivalent initial energies.

The steels RR and RK showed somewhat greater consistency throughout than steel G with respect to transition temperatures based on different criteria. For example, in Series 1 tests of Type A nonstandard specimens, the steels E and Dr show consistent values for transition temperatures while steels G and Dn give widely different values for the various criteria.

The data for transition temperatures of Charpy V-notch specimens of steel A are given in Table 3S. They show that on the basis of one-half the maximum energy or one-half the range from ductile to brittle fracture, the transition temperatures are practically indistinguishable. The transition temperatures based on the curve plotted for fracture appearance vs. temperature (this curve is not shown) was the same for the two energies.

Table 3S—Charpy V-Notch Impact Tests of Steel A

Initial energy, ft.-lb.	Transition temperature in °F. estimated from: Energy: ½ maximum	Energy: ½ range	Fracture appearance: ½ range	Fracture appearance: 50% shear
220	90	80	120	105
110	90	70	120	115

Table 4S—Charpy Keyhole-Notch Impact Tests of Steel A

Initial energy, ft.-lb.	Transition temperature in °F. estimated from: Energy: ½ maximum	Energy: ½ range	Fracture appearance: ½ range	Fracture appearance: 50% shear
220	5	0	50	60
110	0	0	50	40
45	0	−5	40	40

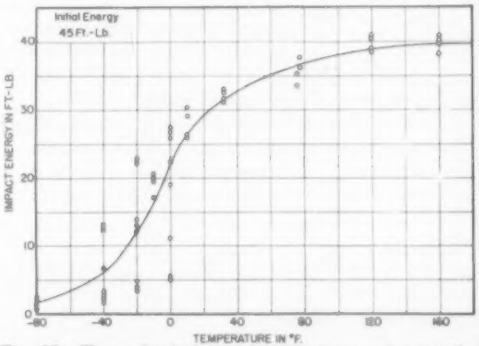

Fig. 7S Charpy keyhole-notch impact tests of semikilled steel A, as-rolled; 45 ft.-lb. initial energy

The curves, however, as shown in Fig. 5S gave no sharp indication of a transition temperature, due possibly to the severity of the stress raiser represented by the V-notch.

The data for transition temperatures of Charpy keyhole-notch specimens of steel A are given in Table 4S. They show that there is little difference in the transition temperature based on energy absorption for the three levels of initial energy used. The regions of rapidly decreasing energy values in Figs. 6S and 7S were considered to be the transition regions. As shown in Table 4S, if the transition temperature is estimated from the fracture appearance, higher temperatures are found because there is not a region of rapidly decreasing values in the curves of fracture appearance vs. temperature of test. However, there is a large difference in transition temperature between the V-notch tests and the keyhole-notch tests. This difference is shown in a comparison of Tables 3S and 4S and is of the order of 80 to 90° F. for transition temperature based on energy absorption. The transition temperatures of the axial tension impact tests of steel A were, respectively, 105, 85 and 80° F. for initial energy of 220, 110 and 45 ft.-lb., and these temperatures are closer to the transition temperature of the Charpy V-notch tests than that of the keyhole-notch tests.

CONCLUSIONS

The results of the supplementary tests reported herein support the hypothesis that notch-sensitive steels exhibit practically no change in transition temperature as determined from axial tension impact tests at different initial energy levels between 220 and 45 ft.-lb. However, nonsensitive steels do indicate a definite although slight decrease in transition temperature with lower initial energies. The presence or absence of change in the transition temperature in axial impact seems to be a more reliable guide to the behavior of the steels in static tests of notched wide plate specimens than is the absolute value of the transition temperature for the impact test.

However, a similar effect of initial energy (or possibly of initial velocity) is not obtained in flexural impact tests of either V-notch or keyhole-notch specimens.

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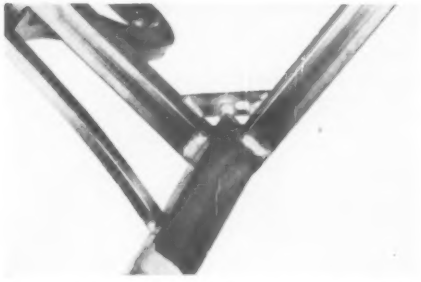

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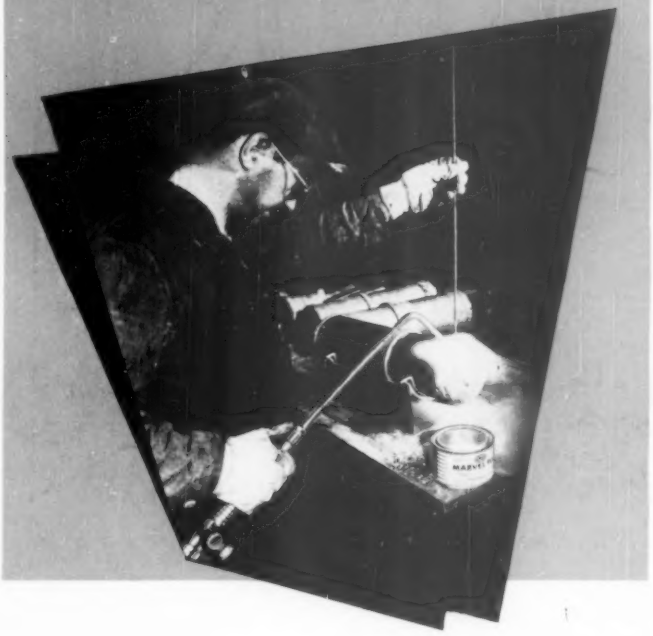

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